

Quality Infrastructure for Climate Change Mitigation and Adaptation to Climate Change

Potentials, opportunities and chances in Sub-Saharan Africa



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On behalf of the German federal government, the Physikalisch-Technische Bundesanstalt (PTB) promotes the improvement of framework conditions for economic activity, thereby supporting the establishment of metrology.



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Part 1 – Introduction

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This chapter provides information about the context, objective and methodology of this study. It introduces the main concepts which lie at the heart of the research used in the study – climate change and quality infrastructure – in the setting of Sub-Saharan Africa. Finally, it examines the relationship between climate change and quality infrastructure.

1.1. General overview

When DIN Norm 1 (which regulates the size of taper pins) was published in 1918, concentration of greenhouse gases in the atmosphere was 295 ppm and therefore just 15 ppm higher than in preindustrial times. In 2017, greenhouse gas concentration consistently exceeded 400 ppm, and the consequences of ongoing climate change affect humans, ecosystems and infrastructures around the world. For these reasons, climate change is considered one of the central challenges of the 21st century. In its Fifth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) has forecasted an increase of global average temperatures of 1.5–4.0°Celsius by the end of this century.

Climate change mitigation and adaptation to climate change can reduce and manage climate change impacts and risks:

- The last two decades have seen relatively active efforts around the world to design and adopt policies which mitigate the emissions of pollutants which affect the climate (Victor et al. 2014:113). The IPCC suggests that mitigating emissions in a way which would be cost-effective and consistent, and would likely avoid warming of more than 2° Celsius, necessitates that nearly all governments engage immediately in international co-operation, adopt stringent national and international emission control policies and rapidly deploy a wide array of low- and zero-emission technologies.

- Adaptation has emerged as a central area in climate change research, in country-level planning and in implementation of climate change strategies (Field et al. 2014:40). Adaptation experience is accumulating across regions in the public and private sectors and within communities. Governments at various levels are starting to develop adaptation plans and policies and to integrate climate change considerations into broader development plans. Yet uncertainties often still exist concerning the right approach to be taken for making adaptation last where it is needed the most: among vulnerable sectors of the population.

Quality infrastructure services play a crucial role here, as they are required to ensure product quality as well as process and system efficiency across a broad range of sectors which are relevant for climate change mitigation and adaptation to climate change. At the same time, quality infrastructure services are needed to generate reliable information for monitoring climate change, thus creating the basis for decision-making and the definition of appropriate adaptation measures. This study identifies the need for quality infrastructure services in times of climate change for six selected sectors deemed highly relevant for climate change mitigation and adaptation to climate change.

Sub-Saharan Africa is a relevant and important study topic in the context of quality infrastructure for climate change mitigation and adaptation to climate change. While it is one of the least greenhouse gas-emitting regions in the world, meaning that mitigation measures have not ranked high on the political agenda to date, the region faces a multitude of risks because of climate change. In view of this, taking systematic and comprehensive approaches for both mitigation and adaptation is of fundamental importance for the future socioeconomic development of these countries and contributes to the achievement of the Sustainable Development Goals (SDGs).

1.2. Objective of the study

The objective of the study presented here is to analyze the contribution and significance of quality infrastructure in Sub-Saharan Africa for both climate change mitigation (renewable energies, energy efficiency) and adaptation to climate change (water, agriculture, human health and meteorology). After a general overview of the region in terms of the existing demand for quality infrastructure, the study takes a closer look at the status quo of quality infrastructure services which already exist in four selected country studies (Benin, Ethiopia, Kenya and Uganda). The study's central research questions are:

- What is the significance of quality infrastructure in the context of climate change for Sub-Saharan Africa?
- In which sectors can quality infrastructure make a substantial contribution for climate change mitigation and adaptation to climate change?
- Which services of quality infrastructure are particularly relevant for which sectors, both in general and in Sub-Saharan Africa?
- Which of the required services already exist and which opportunities for their development exist in selected countries in Sub-Saharan Africa?
- What kinds of climate financing schemes are relevant and in place for supporting the further development of quality infrastructure projects throughout the region?

1.3. Methodology

The methodological approach for the study was based on the analysis of selected sectors and on a subsequent case study approach of four countries located in Sub-Saharan Africa.

Sector studies (see Chapter 2)

The study was implemented in collaboration with experts from the following sectors: energy efficiency, renewable energies, water, agriculture, human health and meteorology. These sectors were chosen because of their relevance and importance in the context of climate change mitigation and/or adaptation to climate change.

Renewable energies and energy efficiency play an instrumental role for climate change mitigation. In the renewable energies sector, hydropower, solar photovoltaic and solar thermal are included as relevant sub-sectors. The cooling, freezing and air-conditioning industries are analyzed with a view to energy efficiency.

In terms of adaptation to climate change, meteorology, water, agriculture and human health build the focus of the study. For meteorology, the analysis focusses on the type of measurements (manual stations, automated stations and remote sensing techniques), equipment, sampling procedures, data storage and processing. For the human health sector, focus is placed on hygiene measures for infection prevention and control, health monitoring and the medical laboratory infrastructure. In the water sector, drinking water distribution systems, waste water systems and sanitation systems are analyzed, as are water efficiency in agriculture and industry. Lastly, for agriculture, the study focusses on the following topics: production, import and distribution of drought stress-tolerant & pest-resistant seeds, pesticides and fertilizers, water management (irrigation, soil moisture), plant protection (pesticide management and application), soil nutrient management and post-harvest climate-proof storage facilities.

Generally, the approach to assessing chances and opportunities for quality infrastructure services is based on the identification of value chains and their components throughout the selected sectors. Based on this, quality challenges are identified and necessary services of the quality infrastructure are described in terms of the main pillars of quality infrastructure (*metrology, standardization, testing, certification, inspection, accreditation and regulation/transversal aspects; see template table on page 7*).

Country studies (see Chapter 3)

Country studies were carried out in June and July of 2017. The objective of the country studies was to assess the development status of quality infrastructure and existing country-based initiatives relevant for the study. Some of the main criteria for the selection of the countries were: previous cooperation and experience with PTB; compatibility with BMZ strategies; the prevailing status of quality infrastructure; and the presence of political foundations. After a comprehensive analysis of these criteria, four case-study countries were selected: Kenya, Uganda, Benin and Ethiopia. In-depth analysis and on-site research were

Quality infrastructure services	Quality challenges	Metrology	Standardization	Testing	Certification	Inspection	Accreditation	Regulation/transversal aspects
Maintenance								
Installation								
Planning								
Transport								
Manufacturing								

conducted in Kenya and Uganda, while quality infrastructure services in Ethiopia and Benin were assessed based on desk research and phone interviews.

Key entities which were included in the study included national metrology institutes, national standards bodies, national accreditation bodies, and conformity assessment bodies. Furthermore, meetings were held with key sectoral institutions such as laboratory associations, associations of water supply companies, national institutes of meteorology and climate change entities.

1.4. Climate change in Sub-Saharan Africa

Of the world's continents, Africa is the most vulnerable to the impacts of climate change. The 2014 Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) states the high exposition and sensitivity of African countries to climate change while having a low adaptive capacity (Niang et al. 2014). Building on previous Assessment Reports, the IPCC confirms that evidence of warming over land regions across Africa, consistent with anthropogenic climate change, has further increased.

Analyses of temperatures conducted on a ten-year basis strongly point to an increased warming trend across the continent over the last 50 to 100 years. Warming projections indicate that, under high emission scenarios, all areas of Africa will exceed 2°C by the last two decades of this century relative to the final mean annual temperature of the 20th century. Additionally, it is likely that land temperatures over Africa will rise faster than the global land

average, particularly in the more arid regions, and that the rate of increase in minimum temperatures will exceed that of maximum temperatures (Niang et al. 2014).

Sub-Saharan Africa, which comprises 49 of the 54 African countries and has a total population of more than 970 million people, has particularly high demand for cautious and sustained attention when dealing with the global consequences of climate change. Global Circulation Models suggest that southern Africa will warm by between 3.1°C and 3.4°C, with warming of up to 4.8°C possible towards the end of the 21st century (Christensen et al. 2007). The projections show reduced rainfall for much of the region in winter (May to July). In mid- to late summer (December to April), precipitation is indicated in the eastern and northern parts of the region. However, there is still considerable uncertainty over rainfall changes in the summer rainfall regions. Despite existing uncertainties, it appears that the frequency and intensity of droughts has already worsened in some parts of the region. The total water available in the large basins of the Niger and Senegal Rivers and Lake Chad has decreased by 40–60% over the past few decades (UNFCCC 2006), while mean precipitation is projected to decline further, especially in the southern and south-western parts of Africa.

At the same time, Sub-Saharan Africa accounts for less than 3% of the world's carbon dioxide emissions from energy and industrial sources. According to the World Bank (The World Bank 2017), Sub-Saharan Africa's per capita emissions of carbon dioxide in 2013 were 0.8 metric tons per person, compared with 6.7 metric tons per person in the European Union. Sub-Saharan Africa is therefore one of the least greenhouse gas-emitting regions in the world,

meaning that mitigation measures have not ranked high on the political agenda to date.

With predictions that temperatures will rise further, Sub-Saharan Africa is expected to face a wide range of impacts, including increased drought and floods. In the near future, climate change will contribute to decreasing water availability, will put constraints on agricultural systems and food security and will mean new risks to human health, including the spread of waterborne diseases and the risk of malaria (UNFCCC 2006).

Concerning key socioeconomic sectors, the Fifth Assessment Report of the IPCC points out that:

- a. Climate change will amplify the existing stress on water availability in Africa. Water resources are subject to high hydro-climatic variability over space and time, and are a key constraint on the continent's continued economic development.
- b. Climate change will interact with non-climate drivers and stressors to exacerbate vulnerability of agricultural systems, particularly in semi-arid areas. Increasing temperatures and changes in precipitation are very likely to reduce cereal crop productivity.
- c. Point b. will have strong adverse effects on food security. Recent progress made in food production will not be sufficient to address the long-term impacts of climate change. New evidence shows that high-value perennial crops could also be adversely affected by temperature rise. Pests, weeds and disease pressure on crops and livestock are expected to increase as a result of climate change combined with other factors. Moreover, new challenges to food security are emerging as a result of strong urbanization trends on the continent and increasingly global food chains. Such food chains require better understanding of the multi-stressor context of food and livelihood security in both urban and rural contexts in Africa.
- d. Finally, climate change may increase the burden of a range of climate-relevant health outcomes. Climate change is a multiplier of existing health vulnerabilities, including insufficient access to safe water and improved sanitation, food insecurity and limited access to health care and education. Evidence is growing that highland areas, especially in East Africa, could experience

increased malaria epidemics due to climate change while the disease burden of meningococcal meningitis and the frequency of leishmaniasis epidemics could also worsen. Additionally, climate change is projected to increase the burden of malnutrition, with the highest toll expected in children.

Due to these prevailing challenges, including the populations' high sensitivity and limited adaptive capacity, Sub-Saharan Africa faces a multitude of risks due to climate change. While climate change is forecasted to bring a new layer of risk for sustainable development, taking systematic and comprehensive approaches for adaptation to climate change is fundamental for the future socioeconomic development of the countries of Sub-Saharan Africa.

1.5. Quality infrastructure in Sub-Saharan Africa

The national quality infrastructure, as illustrated in Figure 1, comprises the following elements:

- **Standardization** is coordinated by the national standardization body, which is responsible for the development and publication of standards, for awareness raising and for the provision of related information.
- **Metrology** is the science of correct and reliable measurements for legal matters, industry and science. The national metrology institute provides traceability for secondary laboratories and ensures accuracy through calibration services.
- **Testing** allows the characteristics or performance of a product or process to be determined following a specific procedure. It is important for research, for quality control, and to ensure health and safety, as well as compliance with contractual or regulatory requirements.
- Furthermore, **inspection** services can be used to determine whether a product or process complies with certain requirements.
- **Certification** is usually based on testing and inspection and provides assurance that a product or process complies with a standard or specification.

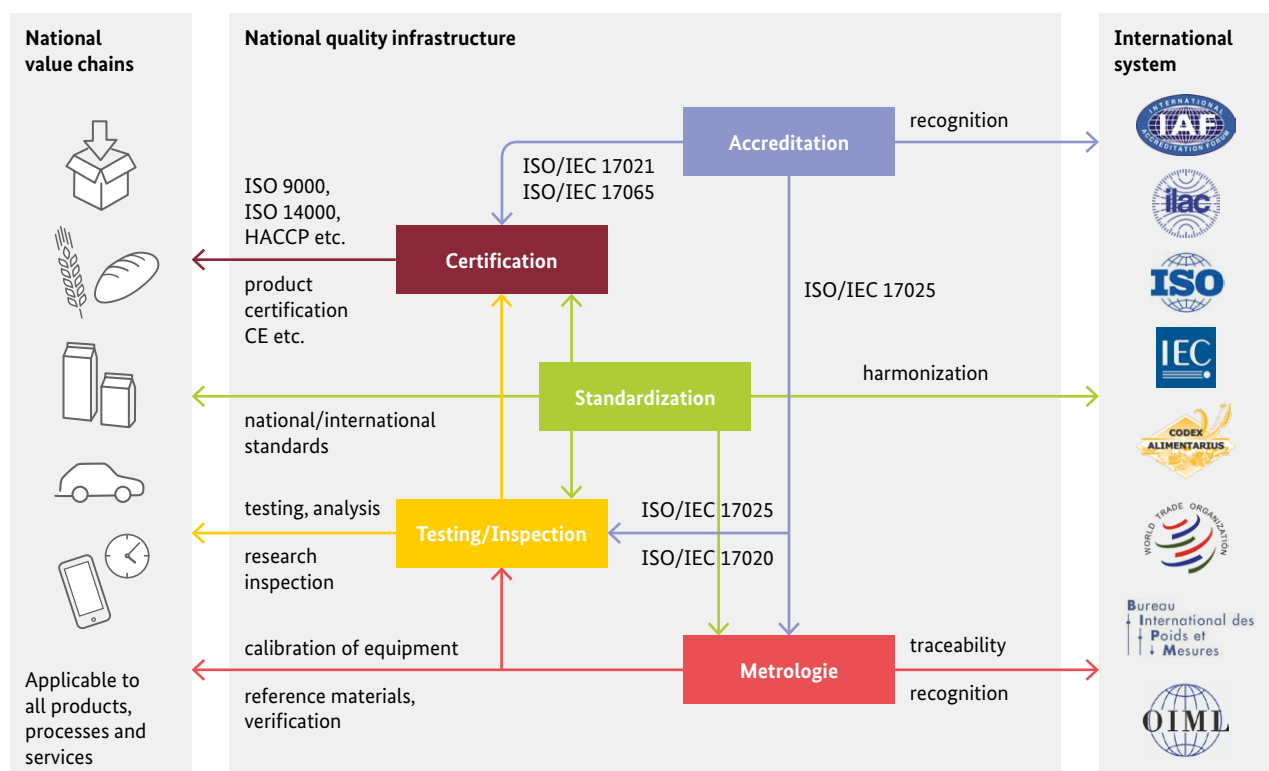


Figure 1: The national quality infrastructure (PTB)

- Finally, **accreditation** is provided by the National Accreditation Body and consists in a formal recognition of an organization's competence to carry out a specific conformity assessment task. Testing and calibration laboratories as well as certification and inspection bodies can apply for accreditation to prove that they are able to provide reliable services.¹

The national quality infrastructure is an interrelated system in which no component can be developed without developing the others, as they complement each other. Furthermore, the national policy framework and relevant public institutions are to be seen as a part of the quality infrastructure as they establish the framework for the different services (Sanetra and Marbán 2007).

In Sub-Saharan Africa, the development of national quality infrastructure varies considerably between different countries. Some nations have established one body in charge of all quality infrastructure services; others have separate institutes placed under different ministries. In many countries, structures for standardization, metrology, testing and inspection exist, while certification is often provided mainly through the offices of international service providers. National accreditation bodies have been established in South Africa, Kenya, Ethiopia, Mauritius and Nigeria. In other countries, accreditation is organized on a regional level: The Southern Africa Development Community Accreditation System (SADCAS), for example, provides accreditation services for 13 countries. A similar structure is being discussed in the context of the Economic Community of West African States (ECOWAS) (see section 3.4. on Benin).

¹ This report differentiates between standards and guidance documents, whereby according to ISO (2017b) international standards "provide rules, guidelines or characteristics for activities or for their results, aimed at achieving the optimum degree of order in a given context", while guidance documents aim to assist users in understanding and implementing a specific standard.

The national quality infrastructure should not be developed in an isolated way, but linked to the international and regional systems by establishing the respective relations. Only in this way is it possible to ensure international traceability, comparability and recognition of local services and benefit fully from the national quality infrastructure.

The national standardization bodies of 34 of the 49 Sub-Saharan African countries are members or correspondent members of the International Organization for Standardization (ISO) (ISO 2017a). South Africa, Kenya and Nigeria are also members of the International Electrotechnical Commission (IEC) (IEC 2017). In metrology, only the national metrology institutes of Kenya and South Africa are full members of the International Bureau of Weights and Measures (BIPM) (BIPM 2017), while six more countries are associate members of the organization. 19 countries are members or correspondent members of the International Organization of Legal Metrology (OIML) (OIML 2017). Of the National Accreditation Bodies mentioned above, the South Africa National Accreditation System and the Southern Africa Development Community Accreditation System are full members of the International Laboratory Accreditation Cooperation (ILAC) (ILAC 2017); Ethiopia, Kenya and Mauritius are associate members and Nigeria is an affiliate. Ethiopia, Kenya, Mauritius and South Africa are also members of the International Accreditation Forum (IAF) (IAF 2017).

The respective regional organizations play an important role in coordinating the development of quality infrastructure regionally. In Africa, these are the African Organisation for Standardisation (ARSO) with 32 members from Sub-Saharan Africa (ARSO 2017), the Intra-Africa Metrology System (AFRIMETS) with 20 members in the sub-region (AFRIMETS 2017) and the African Accreditation Cooperation (AFRAC), whose Sub-Saharan African members are Kenya, Mauritius, Ethiopia, South Africa and the Southern Africa Development Community Accreditation System. Nigeria and the West African Accreditation System, established by francophone states in Western Africa, are associate members (AFRAC 2017). Furthermore, regional economic communities and associations with a development focus, such as the East African Community (EAC), the Economic Community of West African States (ECOWAS) or the Southern African Development Community (SADC) foster the regional harmonization of quality infrastructure services. These regional and sub-

regional organizations are well positioned to guide the development of necessary quality infrastructure services and foster collaboration. Especially in the context of climate change, all of these elements will have key importance in assessing the demand and supply of relevant quality infrastructure services and coordinating the establishment of services needed nationally or in specialized regional hubs. The organizations represent important platforms for the division of tasks and the coordination of activities across countries.

1.6. Quality infrastructure and climate change

Despite implementation limitations, national and regional adaptation experience acquired to date has brought with it valuable lessons for enhancing and scaling up the adaptation response, including principles for good practice and integrated approaches to adaptation.

Five common principles for adaptation and building adaptive capacity are distilled in the Fifth Assessment Report of IPCC:

1. supporting autonomous adaptation through a policy which recognizes the multiple-stressor nature of vulnerable livelihoods;
2. increasing attention to the cultural, ethical and rights considerations of adaptation by increasing the participation of women, youth and poor and vulnerable people in adaptation policy and implementation;
3. combining “soft path” options and flexible and iterative learning approaches with technological and infrastructural approaches and blending scientific, local and indigenous knowledge when developing adaptation strategies;
4. focussing on building resilience and implementing low-regrets adaptation with development synergies in the face of future climate and socioeconomic uncertainties; and
5. building adaptive management as well as social and institutional learning into adaptation processes at all levels.

Additionally, IPCC puts emphasis on ecosystem-based approaches and pro-poor integrated adaptation-mitigation initiatives which hold promise for a more sustainable and system-oriented approach to adaptation. In addition, it promotes equity goals which are of key importance for future resilience by emphasizing gender aspects and highly vulnerable groups such as children (Niang et al. 2014).

Within this overall framework for adaptation and building capacity, links between quality infrastructure services and climate change have not yet been identified systematically. However, quality infrastructure can contribute substantially to the success of each of the above-mentioned adaptation principles, as well as support mitigation approaches which will be just as important.

Quality management can address climate change issues in two ways:

- a. First, quality management allows objectives to be reached effectively and efficiently. These objectives may include climate change mitigation or adaptation, sustainable development or the achievement of a specific Sustainable Development Goal and may thus directly address climate change.
- b. Second, the standard ISO 9001:2015 highlights the importance of risk management for quality management. Risks should be systematically assessed and reduced. This approach is highly relevant in the context of climate change, due to the effects of which people and systems are exposed to increased risks.

In order for quality management to be effectively implemented, quality infrastructure services are essential. Some specific services have already been developed on a global scale to address climate change-related issues. Examples include services in the area of greenhouse gas management, climate-friendly technologies and international standards on adaptation measures. Such services need to be made available by quality infrastructure organizations worldwide; additional services which have been adapted to the specific regional context and demand have to be developed in order to tap the potential from systematic quality assurance in climate change mitigation and adaptation efforts.

In order to further systemize the potential for quality infrastructure services to provide solutions to climate change mitigation and adaptation challenges, and in order to develop these solutions, collaboration between the relevant stakeholders involved will be necessary (nationally, regionally and globally). Systematic consideration of the quality perspective in strategy development in the context of climate change, together with a continuous exchange between stakeholders from the public, private and quality sectors, will allow the adequate use of quality infrastructure services to be fostered and the services necessary to better address issues related to climate change to be developed.



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Part 2 – Demand for Quality Infrastructure Services for Climate Change Mitigation and Adaptation to Climate Change in Sub-Saharan Africa

In this chapter, the sectors of renewable energies, energy efficiency, meteorology, agriculture, water and human health are analyzed concerning current trends related to climate change, the significance of quality infrastructure services, the most relevant sub-sectors in Sub-Saharan Africa and related demand for quality infrastructure services.

2.1. Renewable energies

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2.1.1. Current trends in the sector in times of climate change (global and regional)

Renewable energies play a key role in climate change mitigation efforts worldwide and can support a country's energy self-sufficiency (IRENA 2013:9). This is particularly important in developing and emerging countries which have a growing population, increasing electricity needs and low electrification rates. Moreover, some renewable energy technologies such as solar photovoltaic, solar thermal and mini-hydropower installations are well adapted for distributed generation and can support the electrification of rural areas (Agostinelli 2017).

Energy demand in Africa has grown by over 45% since the year 2000 and electrification efforts in many countries cannot keep up with population growth. Energy supply thus remains low, despite the wealth of energy sources available on the continent. The main issues in Africa's en-

ergy sector are the insufficient capacity and low access to electricity, the poor reliability of the electricity grid and high costs (Agostinelli 2017). It is expected that energy demand will increase substantially in the coming decades as a result of megatrends such as urban population growth and economic development (EUEI PDF 2017).

Sub-Saharan Africa has great potential for renewable energies. As early as 2010, 60% of energy was generated with hydropower plants in the region and several countries have conducted resource assessments and identified potential for solar power, additional hydropower installations, wind energy, biomass and, in Eastern Africa, geothermal energy (IRENA 2013:6-9). In many countries, renewable energies are also competitive in financial terms. In Kenya and Tanzania, for example, the generation costs of solar photovoltaic and biogas are similar to electricity costs from the public grid for commercial and industrial use, and are considerably lower than electricity generated with diesel (Kaiser 2017).

There is also support on the political level. Internationally, the Paris Agreement provides a policy framework for the advancement of renewable energies and fosters technical assistance and investments in African countries to support climate change mitigation measures. Within the framework of the Agreement, national governments submitted climate action plans along with regions and cities in Sub-Saharan African countries. These plans include the expansion of renewable energies (Munang and Mgen-di 2016; EUEI PDF 2017:6). As early as mid-2015, before the Paris Agreement was signed, 35 Sub-Saharan African countries had introduced national renewable energy targets in at least one of the following areas: primary energy supply, final energy consumption, electricity, heating and cooling, and transport (IRENA 2015d).

Furthermore, the Africa Renewable Energy Initiative (AREI) was established to accelerate the expansion of renewable energy capacities across the continent under the mandate of the African Union. The aim of the initiative is to install 10 GW of renewable energy capacities by 2020 and generate 300 GW from renewable sources by 2030 (AREI 2017).

The achievement of the national and regional targets is challenging because, in most Sub-Saharan African countries, a favorable policy and an economic and institutional framework still need to be created; at the same time, the different stakeholders need to coordinate and commit to the targets to enable the expansion of renewable energy capacities (Interview 1). Moreover, at present, administrative hurdles, corruption and aspects such as unclear property titles make the expansion of renewable energies difficult. These circumstances delay the development of renewable energies and can result in considerable deadline pressure once the implementation is underway; this, in combination with cost pressure, can compromise the quality of renewable energy installations, especially if experience with renewable technologies is still limited. The development of solar photovoltaic, for example, is recent in many countries in the region. For this reason, qualified service providers are lacking and services need to be improved. This leads to quality and safety issues – for example, in the installation of rooftop photovoltaic systems. As has been experienced in other developing and emerging economies, the fast development of the technologies in the global market makes it difficult for local industries to keep up. At the same time, capacities to effectively control the quality of imported renewable energy technologies are often lacking. Some countries decide to protect their local industries through local content laws or customs duties, thus creating trade barriers and a national market with limited incentives to be competitive concerning quality (Telfser et al. 2016). Negative experiences with new technologies can damage their reputation and make investors reluctant to support further projects (IRENA 2015b:8).

assurance, capabilities and capacities of the local industry and service providers, and by time constraints. The establishment of a functioning quality infrastructure is thus essential if the expectations of policy makers, investors and consumers are to be met. Quality infrastructure services help to increase the quality and safety of renewable energy installations and provide consumers with confidence in this technology. Quality assurance and support services are necessary throughout the value chain.

The International Renewable Energy Agency (IRENA) has identified several benefits of a functioning quality infrastructure for policy makers, manufacturers, professionals and end users. For policy makers, quality infrastructure enables the detection of low-quality products, which allows growing markets to be protected and strengthened and economic growth to be stimulated. Moreover, it helps provide assurance that the renewable energy installations will perform according to expectations, thus supporting the financial viability of the technologies and increasing the return on investment, including that of public incentives for renewable energies. For manufacturers, quality infrastructure can open new markets if locally provided quality infrastructure services are internationally recognized and prove the quality of local products. Through testing and certification, as well as through the implementation of a quality management system in accordance with international standards, products and manufacturing quality can be improved. For the renewable energy industry, certification (for instance, of installers) facilitates hiring processes and improves the competitiveness of service providers. This, in turn, results in higher wages and more mobility for professionals and attracts talent to the industry. Finally, for end users, a functioning quality infrastructure creates confidence in products and allows products to be compared based on trustworthy third-party information on performance and durability. Quality infrastructure also increases confidence of financial organizations and investors in technology, making more financial resources available for the sector (IRENA 2015b:8-13).

2.1.2. Significance of quality infrastructure services

As mentioned above, the achievement of national targets is jeopardized by lacking quality due to insufficient coordination between different stakeholders, by lacking quality

2.1.3. Identification of sub-sectors relevant in Sub-Saharan Africa

The selection of renewable energy types for this study is based on an evaluation of their relevance for the energy supply in Sub-Saharan Africa at present and in the

future, the relevance of quality infrastructure services for the technology throughout the value chain and their relevance for socio-economic development.²

Solar photovoltaic is starting to be developed across Africa, with some countries including South Africa and Kenya making sizable investments in this technology. According to projections by the International Renewable Energy Agency, this technology is poised to grow considerably: Its application in solar home systems and mini-hybrid grids makes solar photovoltaic an interesting option for rural electrification. Photovoltaic power plants themselves, as well as their manufacturing, installation and maintenance, have important positive socio-economic impacts. Quality infrastructure services are essential throughout the value chain. All solar photovoltaic technologies and installations of all sizes, including grid-connected ground-mounted and rooftop plants, as well as small-scale off-grid systems are considered in the study.

Hydropower is currently one of the main renewable energy sources in Sub-Saharan Africa, yet only a fraction of its existing potential is in use. The possibility of installing large-scale as well as mini- and micro-hydropower plants makes it an interesting option for urban as well as rural electrification. Quality infrastructure services are relevant in manufacturing, planning, construction and operation of the plants. This study considers hydropower installations of all sizes and designs.

Solar thermal power is applied to a limited extent at the moment, but is projected to gain in importance in the future for application in both buildings and industry. Manufacturing and installation require low technology investments, creating development opportunities for local small and medium enterprises. This energy type depends on quality infrastructure services primarily with regard to correct manufacturing, planning and installation. The focus of this study lies on solar water heating systems of all sizes. Electricity generation with solar thermal energy and Concentrated Solar Power (CSP) are not considered, due to their limited relevance in Sub-Saharan Africa.

Wind power is currently of limited importance in Sub-Saharan Africa. Although its share in the energy mix is projected to grow, its importance in the energy mix will remain relatively low. The technology requires consid-

erable investments and is not easily accessible for local small and medium enterprises. Wind power is therefore not considered in this study.

Biogas is mainly used in rural areas at present, providing an alternative energy source used principally for cooking in Sub-Saharan Africa. The contributions to sustainable development are positive, especially due to the substitution of fire wood. However, acceptance of this technology is frequently low, and maintenance is not ensured. Considering the projections of rural electrification based on photovoltaic, its importance in the total energy mix is expected to decrease. Biogas is therefore not considered in this study.

Geothermal energy is mainly important in Eastern Africa (e.g. Kenya and Ethiopia). Due to its lacking relevance for other Sub-Saharan African countries, as well as its relatively low impact on sustainable development because of the high investments needed, it is not included in this study.

2.1.4. Demand for quality infrastructure services in Sub-Saharan Africa for the sub-sectors identified

Solar photovoltaic and solar thermal water heating

The study focusses on two technologies which are powered by the sun: solar photovoltaic and solar thermal water heating. Although the two technologies are substantially different in the way they convert sunlight into energy, risks occur at similar stages and for similar reasons along the value chain, resulting in similar demand for quality infrastructure services in order to ensure quality. Quality gaps can occur along the respective value chain and can have a substantial impact on the long-term performance of the plant.

Assurance of product quality is crucial for all components of solar photovoltaic and solar thermal systems. In many countries, quality control of imported products is lacking and the market is exposed to low-quality imports (Interview 1). Maintaining quality controls for solar photovoltaic components, solar thermal components and complete thermal systems is further complicated by the large number of component providers active on the global market (Interviews 2 & 3).

² Evaluation by the authors based on: IRENA (2015a) Africa 2030: Roadmap for a Renewable Energy Future.

Regarding the manufacturing of components, the situation is different for solar photovoltaic compared to solar thermal. Within the framework of this study, only one South African company could be identified which produced photovoltaic cells in Sub-Saharan Africa (Barbee 2016), and there are only a small number of photovoltaic module manufacturers in the region. Furthermore, inverters for grid-connected solar photovoltaic installations are mainly imported. The development of quality infrastructure services for quality assurance in photovoltaic module and inverter manufacturing is thus less urgent at present (it is expected that it will be more important in the future). In contrast, in several countries in Sub-Saharan Africa, solar thermal systems are being manufactured (Interviews 1, 2 & 3). Quality assurance for manufacturing – from raw material to product – is thus very important for this technology.

For planning and site selection, the availability of reliable irradiation data is of utmost importance for both technology types, as it determines the performance potential of the plant (IRENA 2015c; Telfser et al. 2016). Often, imprecise satellite data and estimations are used, resulting in unrealistic performance predictions. For photovoltaic power plants, considerable know-how is needed to successfully plan a plant, as a variety of factors need to be taken into consideration, including orientation, shading, wind conditions, seismic information and, in the case of rooftop installations, building and rooftop conditions. Moreover, the choice of the correct components is crucial. The chosen technology needs to be matched to the local climatic conditions; for on-grid installations, the inverter needs to be adequate for the system which is being built (Telfser et al. 2016). Furthermore, for solar thermal installations, choosing the right technology is of key importance. In addition, the orientation of the installation is a determining factor for the performance of solar water heaters (Interview 2).

Problems also arise due to installers lacking know-how and experience (Interview 1; IRENA 2015c; Telfser et al. 2016). Installation faults are very common in photovoltaic plants worldwide. A study by TÜV Rheinland identified that, throughout the world, installation faults were the cause of more than 50% of serious defects in photovoltaic plants (TÜV Rheinland 2015). Incorrect installation, often due to minor errors such as loose screws or incorrectly inserted connectors, can thus have devastating effects on plant performance and financial returns. According to

a study of the Solar Bankability project of the European Union, improper installation has the highest financial impact among the most common issues related to modules and inverters (Solar Bankability 2016:61-63). Despite solar thermal technology being comparatively less complex, the installation of solar thermal systems requires solid knowledge and can result in complete failure of the system if carried out incorrectly. Unfortunately, many countries worldwide have had negative experiences with solar thermal water heaters (IRENA 2015c:22). A common issue caused by erroneous installation is leakages which result in water entering houses through the roof (Interviews 2 & 3).

Finally, during operations and maintenance, correct monitoring is essential for both solar photovoltaic and solar thermal installations to detect underperformance and take measures accordingly. Moreover, during this phase, cleaning is important for ensuring that the performance potential of the technology installed is not compromised (Telfser et al. 2016).

Table 1 below summarizes the quality issues along the value chains of solar photovoltaic and solar thermal and indicates which quality infrastructure services are relevant for each technology. The relevant quality infrastructure services are explained in more detail in the following sections. Regulation needs and other transversal aspects are summarized at the end of the chapter.

Metrology

Metrological services are of great importance for the sound development of solar energy technologies and are relevant throughout their value chains. For the manufacturing and assembly of components for solar photovoltaic and solar thermal systems, manufacturers should conduct incoming and outgoing product control; at customs, the quality of imported products and material needs to be ensured. Manufacturers and authorities need to regularly calibrate their testing equipment in order to provide reliable results and identify insufficient quality. For solar photovoltaic, the calibration of reference cells is also an important service a national metrology institute should offer to enable local industries to improve the quality of locally produced or assembled photovoltaic modules.

For the planning of solar energy installations (both solar photovoltaic and solar thermal), the calibration of pyranometers is important for ensuring the reliability of data

on solar irradiance. Only with accurate information on irradiance can the potential performance of a plant be determined realistically. Moreover, metrological services are relevant for testing equipment for other important information used as a basis for planning. This includes the calibration of testing equipment such as anemometers to determine wind conditions or the conditions of a building and rooftop where a solar photovoltaic or solar thermal plant should be installed.

Finally, the calibration of testing equipment is also important for the commissioning of solar photovoltaic and solar thermal plants as well as during operations and maintenance, when – depending on the size of the installation – regular performance checks or continuous performance monitoring should be carried out in order to be able to detect underperformance and take necessary measures. For solar thermal installations, for example, calibration of flow meters and thermometers is required.

Standardization

Standards of the IEC are available for each step of the photovoltaic value chain. For components, the standards define safety and design requirements and how the components should be tested, for example. Other IEC standards define requirements for solar photovoltaic systems, including their design, monitoring, capacity and energy evaluation. Additionally, a set of recommendations and guidance documents are available (IEC 2017). A full list of IEC standards related to solar photovoltaic can be found on the following website:³ <https://webstore.iec.ch/search-form&ComNumber=82#>

International standards for solar thermal technologies have been developed by the ISO. They define test methods for solar thermal collectors, specific components and complete systems. A list of available standards can be found on the website of ISO technical committee 180 for solar energy: <https://www.iso.org/committee/54018/x/catalogue/>

Moreover, ISO standards available for the implementation of quality management systems can help to ensure high product quality on manufacturing sites (Solar Bankability 2016) or correct operation and maintenance of large-scale solar energy installations.

The national standards body has an important role in adopting the relevant international standards or adapting them to the local conditions, if necessary. In the case of solar photovoltaic, adaptation of the standards to local climatic conditions may be needed. A hail test for solar photovoltaic modules, for example, might not be relevant in a tropical country, while testing for salt mist might be more important in coastal areas, and exposure to sand and dust is an issue which needs consideration in and near deserts. In order to have the Sub-Saharan African perspective better reflected in international standards, the participation of delegates from the region in the respective IEC working groups is important. Additionally, the coordination of standardization activities on the level of the African Organisation for Standardisation (ARSO) and organizations on the sub-regional level like the East African Community (EAC) is important. This is especially true if adaptations of existing international standards to meet the requirements of the African stakeholders or new regional standards are needed.

Testing, certification and inspection

Testing services are important for component manufacturing, transport, planning, operation and maintenance. Quality tests can be carried out upon the arrival of materials and components for solar energy systems (both solar photovoltaic and solar thermal), as well as at different stages of the production and assembly process of components. International standards define testing methods and specific requirements for different components. As mentioned above, local manufacturing of solar photovoltaic modules and inverters is very limited in Sub-Saharan Africa. Nevertheless, testing capabilities are important for verifying the quality of imported photovoltaic components, protecting the market from low-quality products and detecting fake certificates.

For photovoltaic modules, it is particularly important to be able to test their quality upon arrival, as modules can easily be damaged during transport. If transport damage is not detected and damaged modules are installed, the performance of the photovoltaic power plant can be considerably affected (Solar Bankability 2016).

For the planning of solar photovoltaic and solar thermal plants, long-term data on solar irradiance at potential plant locations is needed. Weather stations and other testing facilities which gather solar irradiance data over long periods play an important role here (IRENA 2015c,

³ The IEC standards for solar photovoltaic are currently being revised.

Telfser et al. 2016). Finally, once the solar photovoltaic or solar thermal installation is in operation, regular performance tests should be carried out to monitor the correct functioning of the plant and to detect underperformance.

Certification is available for photovoltaic components and solar thermal collectors according to international standards. Moreover, certification schemes for engineering, procurement and construction (EPC) contractors which implement large-scale renewable energy projects, as well as for trained installers who carry out the installation of smaller solar photovoltaic or thermal plants or work for EPCs, can be very valuable for both solar energy technologies. Planning, procurement and installation are crucial for the final performance and safety of photovoltaic and solar thermal plants, and certification can provide confidence in the know-how of a particular service provider (IRENA 2015c; Solar Bankability 2016:20). Moreover, the availability of certification schemes can have positive effects on industry development, as it can result in higher wages for certified installers and in market growth thanks to increased confidence in the technology (IRENA 2015b).

Inspection services are relevant for component production, where buyers can require inspection of production facilities before delivery in order to be sure that the manufacturer has the necessary processes in place to ensure product quality (Solar Bankability 2016:19). A commissioning committee, including third party inspectors, should commission larger-scale solar energy plants once they are installed. Regular inspections can also be carried out during the operations and maintenance phase of solar photovoltaic and solar thermal installations in order to ensure correct functioning of the plant (IRENA 2015c; Telfser et al. 2016).

Accreditation

Accreditation services relevant for solar energy include accreditation of testing and calibration laboratories in accordance with ISO/IEC 17025 (ISO 2005), accreditation of certification bodies in accordance with ISO/IEC 17065 (ISO 2012b) and accreditation of inspection bodies in accordance with ISO/IEC 17020 (ISO 2012a). The availability of internationally accredited conformity assessment bodies for solar energy can help to strengthen the development of industry. Locally or regionally available services are generally more affordable than accreditation services from institutions based from locations further away on the continent or in Europe. Accreditation can improve the

investment climate of a country if trustworthy services are locally available and facilitate investments based on reliable information. Moreover, it can support the export of locally manufactured products, such as solar thermal systems.

Hydropower

For hydropower projects, the assurance of quality and safety is most important during planning, installation and operation of the plant. For some aspects, a distinction between different sizes of installations needs to be made. Generally, hydropower is a mature technology and manufacturing of components does not pose major difficulties. Nevertheless, the quality of materials and components used needs to be ensured.

During the planning phase, the greatest challenges lie in selecting an adequate site and minimizing the environmental and social impacts of the plant. Detailed studies need to be carried out. Given the potential impacts of hydropower installations – especially large-scale ones – relevant stakeholders should be involved in decision-making processes (International Rivers 2014). Because assessments and plant design require considerable expertise and experience, all important factors are taken into consideration for site selection, plant optimization and minimization of possible negative impacts. For large-scale as well as small-scale hydropower plants, sufficient water flow and water quantity throughout the year are crucial factors (IEA Small Hydro 2017). Correct determination of the water line is important in this context (Interview 4). Water availability may be subject to great variation in the coming years due to climate change-induced changes in precipitation patterns, increased temperatures and more extreme weather events such as droughts and floods. Therefore, for site selection, historical meteorological data should be considered alongside future predictions (International Rivers 2014:51) (see section 2.3. on meteorology). Lacking or not sufficiently accurate hydrological data considerably increases uncertainties for planning (Interview 4).

For the installation of hydropower plants, the quality and safety of the established infrastructure, – for example, dams – are indispensable. In a worst-case scenario, quality shortcomings in hydropower plants can cause a dam to burst, with potentially devastating effects on the surrounding communities and ecosystems in the case of large-scale hydropower plants. Smaller construction and

installation errors can have negative economic impacts – for example, due to lower long-term performance or the repairs needed. Additionally, they may compromise the safety of employees and surrounding ecosystems.

Quality aspects are also important during operation and maintenance of hydropower plants. This is highly relevant in Sub-Saharan Africa, where more than half of the region's energy is generated via hydropower (IRENA 2013:6-9). However, maintenance and monitoring are often neglected (Interview 4). In addition to the long-term functioning of the technology, water quality upstream and downstream of the plant needs to be monitored in order to detect possible negative impacts on the environment (such as altered levels of dissolved oxygen) and take timely measures (Fondriest Environmental Inc. 2016). Moreover, reservoir management is relevant in the context of climate change in order to limit greenhouse gas emissions (Deemer et al. 2016).

Table 2 summarizes the quality and safety issues along the value chain of hydropower plants and indicates which quality infrastructure services are important in order to respond to these issues. The relevant quality infrastructure services are explained in more detail below. Regulation needs and other transversal aspects are addressed in the last part of this section.

Metrology

Metrological services are important for the quality and safety assurance of hydropower plants throughout the value chain from component manufacturing to operation. The testing equipment used for manufacturing should be calibrated regularly. For site selection, it is important to calibrate the equipment used to determine the water line, flow and quality, to monitor precipitation and to test the soil and foundation. For water quality tests, the national metrology institute can also provide reference material and act as a proficiency test provider as part of their services in chemical metrology. Calibration is also relevant for the testing equipment used for quality control during construction and installation as well as for the monitoring and testing devices used during operation and maintenance (e.g. flow meters, extensometers). Monitoring may include the performance of the plant, the infrastructure, and environmental impacts such as effects on ecosystems and greenhouse gas emissions from the reservoir.

Standardization

Relevant standards for hydropower include technical standards for components such as turbines and electrical generators, for plant design and for the installation, commissioning and control of power plants. Specific standards and guidance documents for hydropower are developed by the Institute of Electrical and Electronics Engineers (IEEE) (ANSI 2017). Some relevant standards have also been developed by IEC and ISO. In order to limit the negative environmental impacts of existing hydropower installations, relevant standards from the ISO 14000 family on environmental management as well as guidance documents for the Environmental Impact Assessment can be applied.

Several international organizations, such as the World Commission on Dams and the International Hydropower Association, are involved in the development of guidance documents and additional tools for the assessment of social and environmental impacts and the systematic integration of sustainability aspects in hydropower development (Scanlon et al. 2004, Interview 4).

Testing, certification and inspection

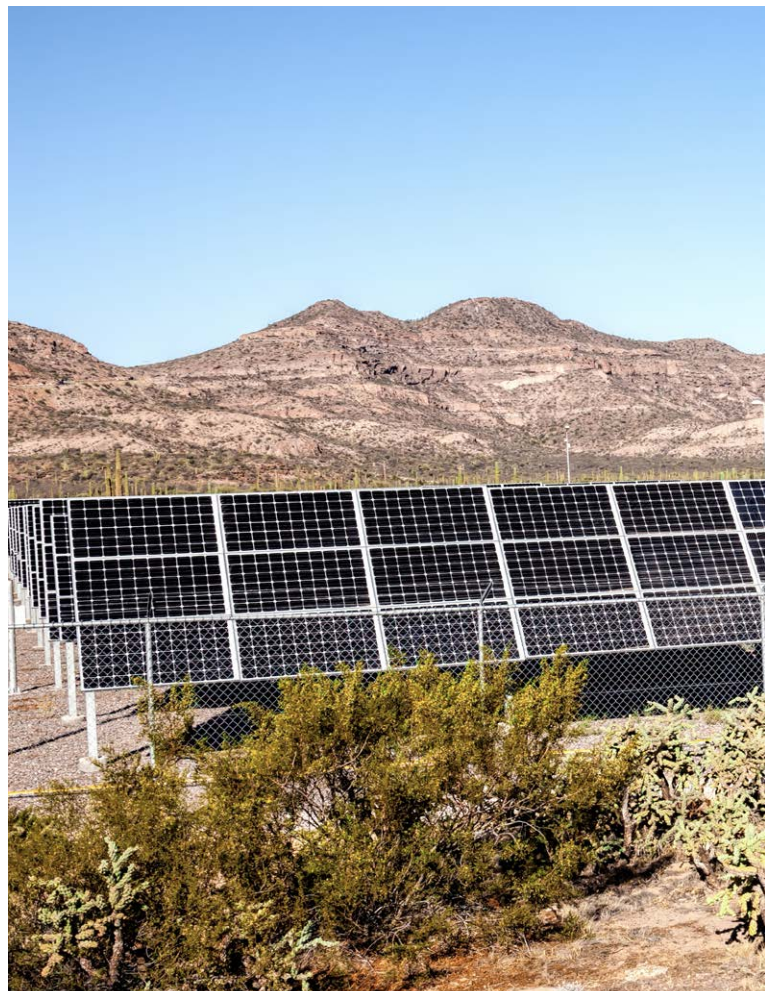
Testing services are important throughout the hydropower value chain. Tests can be conducted to ensure the quality of materials and components from the raw material to the finished product. For the planning phase, tests of on-site water conditions need to be carried out. The water line, flow and quality should be analysed (IEA Small Hydro 2017). Long-term precipitation and temperature data, as well as information about extreme weather events which is usually generated by weather stations and meteorological laboratories, provide important information about the viability of a hydropower plant in a potential location. Furthermore, tests have to be conducted during construction and installation to detect possible faults. In order to monitor the composition of concrete throughout the construction process, testing capacities need to be available locally. For large-scale hydropower projects, on-site laboratories may be set up for this task (Interview 4). During commissioning, the plant has to be tested for safety and correct functioning. Once the plant is in operation, monitoring of water pressure, flow and quality is important in order to be able to detect potential risks for plant performance and negative impacts on the environment and take measures accordingly. Infrastructure monitoring is also necessary: The established volume should be regularly checked for changes in length with an extensometer (Interview 4).

Personnel certification can be relevant for specific service providers such as welders (Bureau Veritas Group 2017). Certification for components helps to select quality inputs for the power plant. In some countries, certification schemes exist for environmentally friendly hydropower plants and ecological power generation. In the United States, for example, the Low Impact Hydropower Institute provides certification for hydropower installations (LIHI 2017), while in Switzerland, the *naturemade* label certifies eco-friendly power generation from hydropower plants, among other sources (Naturemade 2017). However, such certifications are not yet widely used (Interview 4). No information about the application of such labels in Sub-Saharan African countries could be retrieved.

Inspections have to be carried out during the construction and installation of a hydropower plant. Moreover, inspection services are relevant for commissioning – both after the installation has been completed and during operation and maintenance – to ensure that the plant functions correctly.

Accreditation

As explained for solar energy above, accreditation services relevant for hydropower include accreditation of testing and calibration laboratories in accordance with ISO/IEC 17025 (ISO 2005), accreditation of certification bodies in accordance with ISO/IEC 17065 (ISO 2012b) and accreditation of inspection bodies in accordance with ISO/IEC 17020 (ISO 2012a). In the Sub-Saharan African context, accredited laboratory services are important in order to generate accurate information and ensure the reliability of the information needed for planning and monitoring of hydropower projects. Accredited inspection bodies can also ensure quality during installation and carry out competent commissioning of installed plants. As mentioned above, the availability of accreditation services nationally or regionally can considerably reduce the cost of the services.



Transversal needs for quality and safety assurance

For the development of renewable energy technologies, support from local authorities is required. This can be achieved via awareness-raising events and initiatives concerning the need for quality and safety in renewable energies, as well as related risks addressed to stakeholders along the value chain, including end users and investors. Moreover, training programmes for EPCs and installers can be supported in order to improve the capabilities of local service providers.

The authorities also have an important role in regulating the development of the renewable energies sector. Commissioning procedures should be established for the different technologies, and regular or continuous monitoring should be required once the power plant is in operation.

The inclusion of quality and safety criteria in tenders for renewable energy installations is an important step toward promoting quality in the sector, which in turn will foster confidence in new technologies. At the same time, it generates demand for quality infrastructure services and allows national quality infrastructure institutions to sustainably develop additional quality assurance services for renewable energies (Telfser et al. 2016).

Finally, the grid needs to be appropriate for the successful expansion of renewable energies, and grid codes need to be available to ensure secure, safe and economically proper functioning of the electric system. This is particularly relevant for solar photovoltaic, as electricity generation is not constant; here, the grid needs to be sufficiently flexible to allow for the use of renewable energy when it is available.



Quality infra-structure services/ value chain	Quality challenges	Metrology	Standardization	
Maintenance/ monitoring	<ul style="list-style-type: none"> ■ Monitoring of performance ■ Correct maintenance, e.g. cleaning 	<ul style="list-style-type: none"> ■ Calibration of performance testing devices 	<ul style="list-style-type: none"> ■ Procedures and implementation of management systems 	
Installation	<ul style="list-style-type: none"> ■ Correct installation ■ Complete system documentation 	<ul style="list-style-type: none"> ■ Calibration of testing devices 	<ul style="list-style-type: none"> ■ Technical installation ■ Documentation 	
Planning	<ul style="list-style-type: none"> ■ Site selection: ■ Reliable irradiation data ■ Consideration of all relevant information (e.g. orientation, shading, wind and other climatic conditions, seismic information, condition of the foundation and/or building and roof) 	<ul style="list-style-type: none"> ■ Equipment calibration 	<ul style="list-style-type: none"> ■ System design ■ Site selection 	
Transport	<ul style="list-style-type: none"> ■ Prevention and detection of photovoltaic module/ component damages 		<ul style="list-style-type: none"> ■ Criteria for correct transportation 	
Manufacturing	<ul style="list-style-type: none"> ■ Component quality (national and imported) 		<ul style="list-style-type: none"> ■ Component quality ■ Production processes 	

Table 1: Quality issues and necessary services of quality infrastructure along the value chains of solar photovoltaic and solar thermal water heating

Quality infra-structure services/ value chain	Quality challenges	Metrology	Standardization	
Maintenance/ monitoring	<ul style="list-style-type: none"> ■ Correct long-term functioning ■ Water quality upstream/downstream ■ Environmental management of water quality upstream, downstream and reservoir 	<ul style="list-style-type: none"> ■ Equipment calibration ■ Chemical metrology 	<ul style="list-style-type: none"> ■ Maintenance procedures ■ Testing procedures for water quality ■ Management systems for upstream, downstream and reservoir water quality 	
Installation/ construction	<ul style="list-style-type: none"> ■ Infrastructure safety, e.g. dams ■ Correct installation of turbines 	<ul style="list-style-type: none"> ■ Equipment calibration 	<ul style="list-style-type: none"> ■ Infrastructure safety ■ Commissioning 	
Planning	<ul style="list-style-type: none"> ■ Appropriate site selection 	<ul style="list-style-type: none"> ■ Equipment calibration ■ Water quality 	<ul style="list-style-type: none"> ■ Plant design ■ Social and environmental impact assessment 	
Manufacturing	<ul style="list-style-type: none"> ■ Production of high quality components 	<ul style="list-style-type: none"> ■ Equipment calibration 	<ul style="list-style-type: none"> ■ Quality criteria for components ■ Quality management systems 	

Table 2: Quality issues and necessary services of quality infrastructure along the hydropower value chain

	Testing	Certification	Inspection	Accreditation	Regulation/ transversal aspects
	<ul style="list-style-type: none"> ■ Regular performance and safety tests 	<ul style="list-style-type: none"> ■ Quality management systems (e.g. ISO 9001) 	<ul style="list-style-type: none"> ■ Regular inspections of large-scale power plants 	<ul style="list-style-type: none"> ■ Accreditation of laboratories (testing/calibration), certification and inspection bodies 	
	<ul style="list-style-type: none"> ■ Initial performance and safety tests 	<ul style="list-style-type: none"> ■ Training and certification of installers 	<ul style="list-style-type: none"> ■ Commissioning 		<ul style="list-style-type: none"> ■ Commissioning criteria and procedures
	<ul style="list-style-type: none"> ■ Long-term solar irradiance data and data on environmental conditions (e.g. wind speed and precipitation) 		<ul style="list-style-type: none"> ■ Building structure (e.g. for rooftop installations) 		<ul style="list-style-type: none"> ■ Training and awareness raising about quality issues
	<ul style="list-style-type: none"> ■ Performance tests ■ Infrared and electroluminescence tests for photovoltaic modules 	<ul style="list-style-type: none"> ■ Transport procedures / systems 			
	<ul style="list-style-type: none"> ■ Component quality, e.g. performance and durability 	<ul style="list-style-type: none"> ■ Certification of product quality and management systems 	<ul style="list-style-type: none"> ■ Inspection of production facilities 		<ul style="list-style-type: none"> ■ Quality requirements

	Testing	Certification	Inspection	Accreditation	Regulation/ transversal aspects
	<ul style="list-style-type: none"> ■ Water pressure on turbines ■ Water flow ■ Water quality 		<ul style="list-style-type: none"> ■ Regular plant inspections 	<ul style="list-style-type: none"> ■ Accreditation of laboratories (testing/calibration), certification and inspection bodies 	<ul style="list-style-type: none"> ■ Safety requirements for infrastructure
	<ul style="list-style-type: none"> ■ Quality parameters of materials used 	<ul style="list-style-type: none"> ■ Construction material 	<ul style="list-style-type: none"> ■ Infrastructure safety ■ Commissioning 		<ul style="list-style-type: none"> ■ Safety requirements for infrastructure ■ Quality and safety criteria for commissioning
	<ul style="list-style-type: none"> ■ Water quality, flow etc. ■ Precipitation in water catchment ■ Quality of foundation 		<ul style="list-style-type: none"> ■ Plan acceptance 		
	<ul style="list-style-type: none"> ■ Component quality 	<ul style="list-style-type: none"> ■ Component quality 			

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2.2. Energy efficiency

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2.2.1. Current trends in the sector in times of climate change (global and regional)

According to the World Energy Council, the share of energy efficiency in total primary energy consumption (with avoided energy consumption taken into account) in 2014 was 38 % (World Energy Council 2016⁴). Energy efficiency can be considered an energy resource and, due to its contribution to the reduction of CO₂ emissions, one of the most important tools to combat climate change. Consequently, it is becoming a top priority in energy policies worldwide.

In 2011, the Secretary-General of the United Nations launched the Sustainable Energy for All initiative. It has three interlinked objectives to be achieved by 2030, with the second objective being to “double the global rate of improvement in energy efficiency” (SEforALL 2017). This objective was included as a specific target under the seventh of the 17 SDGs (“Ensure access to affordable, reliable, sustainable and modern energy for all”) in the Agenda for Sustainable Development adopted by world leaders in September 2015 at the United Nations Sustainable Development Summit.

Energy efficiency in Africa compared to global data

A general indication of energy efficiency performance is given by primary energy intensity, which relates the total energy consumption of a region or a country to its gross domestic product. Since the year 2000, primary energy intensity has been decreasing globally in all regions except the Middle East. Due to the world economic crisis, however, worldwide energy intensity has decreased less rapidly since 2008 (1.3 % per annum between 2008 and 2014 versus 1.6 % per annum between 2000 and 2008 – World Energy Council 2016). During both periods, the decrease has

been slightly stronger in all countries in Africa compared to the global average. Africa is positioned in the midfield with an intensity of about 1.4 (for Europe, the intensity is 1; for the most (primary) energy-intensive region, it is 2.8). The worldwide rate of power transmission and distribution losses has remained stable since 2000 (8.6 % in 2014), with differences between the regions. Africa shows much greater losses (over 15 % on average), mainly due to poor infrastructure reliability, irregular power supplies and non-technical losses, including theft and unpaid bills, whereas the energy intensity in industry in Africa is the lowest worldwide (World Energy Council 2016).

The average amount of energy consumed per household has been decreasing throughout almost the entire world (by approximately 0.4 % per annum) since 2000. In African countries, the main driver of the reduction in the energy consumed per household is the substitution of biomass with modern fuels for cooking (World Energy Council 2016).

In the service sector (public administration, trade and other service activities), where electricity is generally the main source of energy, the electricity required to generate one unit of value added (the electricity intensity) is increasing in most regions. This trend is mainly linked to the development of information and communication technologies and air conditioning. However, there is still a large discrepancy among regions: Electricity intensity is higher by a factor of 3.5 in North America compared to India or Africa.

The adoption of energy efficiency laws or energy laws with a strong component related to energy efficiency is becoming a common approach worldwide to consolidate the institutional commitment to energy efficiency (World Energy Council 2016). Potential policy measures to enhance energy efficiency at a national level range from regulations and financial and fiscal instruments to monitoring and information. “The impact of regulations depends on their enforcement or on the accompanying measures making enforcement more acceptable. In most regions the share of regulations in the policy toolbox is decreasing” (World Energy Council 2016). In Africa and the Middle East, for example, the share of regulations in energy efficiency policies has dropped from over 60 % in 2009 to below 40 % in 2015 (compared to about 50 % globally on average), whereas the use of financial and other measures (including certification) has strongly increased.

⁴ The percentage indicated was calculated as the difference between current consumption at 1980 energy intensity levels and the actual energy consumption. The energy efficiency indicators in the report were calculated for 96 countries and ten world regions, one of them being Africa as a whole. Out of the 13 countries covered on the continent, 11 are from Sub-Saharan Africa. Several more specific surveys were carried out with lower numbers of surveyed countries.

Minimum energy performance standards and energy efficiency labels

Considering the size and continuous growth of the household appliances market worldwide, equipment efficiency is a very significant aspect of energy efficiency strategies. Governments often resort to establishing Minimum Energy Performance Standards (MEPS) and promoting energy labels for electrical appliances, motors or buildings to remove the inefficient products from the market. Among regulations, mandatory energy efficiency labels are widely implemented and are important for guiding consumers and motivating manufacturers. Energy labels increase the number of efficient appliances by raising awareness about energy performance and by allowing all models and technologies to be compared. They indicate the energy efficiency of products according to pre-set criteria and foster competition between models based on the rating.

Labelling is well developed for refrigerators and is currently mandatory in over 60 countries worldwide (including Ghana and Kenya) and planned in others (among them South Africa, Nigeria, Benin and Ethiopia). Furthermore, air-conditioning labelling is mandatory in about 60 countries worldwide (including Kenya) and planned in others (World Energy Council 2016). However, labels alone are not sufficient to transform the market. They are an important first step, but need to be complemented by Minimum Energy Performance Standards to remove inefficient equipment or practices.

Many countries have requirements associated with the minimum performance of air-conditioning systems, and more and more standards on air-conditioning appliances are being integrated into both building codes and building certificates (World Energy Council 2016). In many cases, governments have measured an increase in the rate of efficiency improvement of new appliances and equipment being sold in their markets after Minimum Energy Performance Standards and labels were introduced.

Example programmes and international initiatives for energy efficiency

There are a number of well-established (national or regional) programmes consisting of Minimum Energy Performance Standards and labels around the world, the best-known being the United States Energy Star, the Japanese Top Runner programme and the European Union's Ecodesign Policy.

Whereas "spill-over" effects from the above programmes have been documented (e.g. a worldwide influence of the European Union label's colour coding and arrows system (EC 2015)), there are negative effects of second-hand appliances imported from OECD countries into the developing world. United for Efficiency (see below) recently documented the example of the second-hand import of appliances to Ghana; here, out of all the imported appliances entering the market, at least 35% were second-hand products which had to be repaired or rejected (U4E 2017b).

The Sustainable Energy for All initiative's (see above, p. 27) Africa Hub is a partnership working to coordinate and facilitate the implementation of the initiative in Africa and the achievement of its 2030 objectives. It provides technical assistance to African countries in the fields of energy access, renewable energy and energy efficiency, and promotes policy advocacy and networking.

United for Efficiency is a global effort supporting developing countries and emerging economies to move their markets to energy-efficient appliances and equipment under the leadership of the United Nations Environment Programme. Within its scope are several high-efficiency product categories, including household refrigerators and room air-conditioning.

Regional and sub-regional trends in Sub-Saharan Africa

Across the region, energy intensity varies enormously, with that of Liberia being nearly 16 times that of Botswana. In Sub-Saharan Africa, reductions in energy intensity became marked after 1998. In 2010, improvements in energy intensity saved the region about 33% of its primary energy consumption.

In 2015, the Sustainable Energy for All initiative conducted country surveys about the main energy efficiency initiatives and efforts undertaken in 24 African countries, 19 of which were in Sub-Saharan Africa. Some of the key findings are the following:

- 50% of the countries surveyed have a published energy efficiency strategy (incl. Chad, Lesotho, Malawi and Sierra Leone);
- A low implementation rate for Minimum Energy Performance Standards and labelling and a lack of regulation enforcing compliance;

- Regarding the mass roll-out of energy efficiency technologies, a lack of quality control on technologies (labelling) and of monitoring & verification were seen as barriers (UNEP 2015).
- A current trend in Sub-Saharan Africa is the creation of new regulations and labels to promote energy efficiency, often fostered by regional programmes. This is the case, for example, in Kenya, where new regulations for the energy efficiency of buildings were published and an efficiency label for appliances was implemented in the last years.

Mandatory appliance standards in Ghana

In the early 2000s, supported by United States institutions, Ghana enacted the first appliance standards regulation in Sub-Saharan Africa. Today, Ghana is operating a mandatory appliance standards and labelling regime under which importers and retailers of room air-conditioning and compact fluorescent lamps are required to import and sell only products which meet Minimum Energy Performance Standards approved by the Ghana Standards Authority. It is a criminal offence to import, display for sale or sell air-conditioning and compact fluorescent lamps in Ghana unless they meet the minimum performance standards and are properly labelled. The legislation started with room air-conditioning, while other products were to follow suit, including refrigerators and deep freezers.

Ghana is a key port of entry for West Africa and much of the continent's interior. Therefore, regional replication of the Ghana model was also intended, but has not materialized yet. The Economic Community of West African States (ECOWAS) plans to develop Minimum Energy Performance Standards for air-conditioning appliances and refrigerators for the entire ECOWAS region. In 2009, Ghana adopted a ban on imports of second-hand refrigeration and air-conditioning equipment which entered into force in January 2013.

2.2.2. Significance of quality infrastructure services

To increase the energy efficiency of appliances in Sub-Saharan Africa, their technology, installation and maintenance have to be continuously improved. Only a very small percentage of the electric appliances used in Sub-Saharan Africa are produced in the region.⁵ At the same time, the appliances are used significantly longer than their projected lifetime in many cases. For this reason, in order to generate the biggest impact on lowering energy consumption and greenhouse gas emissions, measures to increase energy efficiency have to focus on installation and maintenance as well as on market surveillance of imported appliances. The latter is increasingly important in order to prevent markets in Sub-Saharan Africa from being flooded with inefficient second-hand or substandard products from overseas.

Quality infrastructure provides the services required for a systematic quality management in the sector. Hence it is fundamental for increased energy efficiency in Sub-Saharan Africa. The contributions of the components of quality infrastructure may be summarized as follows:

- *Metrology* provides calibration and intercomparisons services which are required by testing laboratories, secondary calibration laboratories and users of testing equipment in the sector (such as installation and maintenance companies). Metrological services are fundamental to ensure traceability and to increase the exactitude of tests and measurements in the sector, thus creating the basis for increased energy efficiency.
- *Standardization* provides commonly agreed criteria for the energy efficiency of products as well as for their installation, maintenance and market surveillance. National and regional standards may define criteria considering specific market requirements in Sub-Saharan Africa – for example, energy ratings based on the market requirements.

⁵ Some production lines for refrigeration and air-conditioning do exist in Sub-Saharan Africa. Chinese and Korean manufacturers of refrigeration and air-conditioning appliances have been active in various countries. Nigeria has become especially interesting for Chinese air-conditioning manufacturers. In the recent past, they have set up production facilities (Haier, Shinco) and assembly lines (Chigo). The production of refrigeration equipment has recently been started in several other Sub-Saharan African countries (South Africa, Zimbabwe, Swaziland and Ethiopia). However, the vast majority of refrigeration and air-conditioning appliances used in Sub-Saharan Africa are imported.

- *Testing, certification and inspection* are required in order to assess conformity of products with energy efficiency criteria. The related services are highly relevant in Sub-Saharan Africa to assess conformity with energy labels and ratings. Testing and inspection services are needed for effective market surveillance which protects consumers from buying sub-standard equipment. Certification services provide crucial information on the fulfilment of quality criteria of energy efficient products as well as their adequate installation and maintenance.
- *The improvement of energy efficiency* in Sub-Saharan Africa requires a systematic and holistic development of the necessary quality infrastructure services. For example, effective market surveillance requires appropriate regulation as well as services of metrology and testing laboratories, inspection and accreditation bodies based on international standards. Not all of the services of quality infrastructure have to be developed nationally. As explained further in subsection 2.2.4., specific services may be offered by more advanced and specialized organizations in the region. In any case, it is important that the sector and relevant authorities have access to the required services of quality infrastructure by enhancing the contacts between the users and providers of quality infrastructure services for energy efficiency.

2.2.3. Identification of sub-sectors relevant in Sub-Saharan Africa

In the area of energy efficiency, the product categories of refrigeration and air-conditioning equipment have been chosen for the following reasons:

High energy consumption and greenhouse gas emissions

These two product groups are highly relevant in terms of energy consumption and direct greenhouse gas emissions (CO₂ and refrigerants with high global warming potential). Considering the CO₂ emissions caused by energy consumption, as well as the direct greenhouse gas emissions due to the use of refrigerants, the two product groups are responsible for over 7% of global greenhouse gas emissions, equivalent to 3.7 gigatons of CO₂ per annum (2014); by 2030, this will increase to 8.1 gigatons of CO₂, when these product groups are estimated to contribute around

13 % to global emissions. Their emissions are growing at a rate which is at least three times faster than the global average increase of greenhouse gas emissions (GCI 2015).

Direct greenhouse gas emissions of refrigerants can occur during normal operation because of leaks from pipes and components. Without appropriate recovery and recycling facilities, most direct emissions occur when the refrigerant is exchanged during regular servicing or when a unit is dismantled (end-of-life emissions). Especially in Sub-Saharan Africa, there is still a low penetration of markets with refrigeration and air-conditioning devices using refrigerants with low global warming potential. Even though the amount of refrigerant in small units is only in the range of several grams to a few kilograms, the high global warming potential of hydrochlorofluorocarbons (HCFCs) and hybrid coaxial fibre means that direct emissions contribute approximately one third of the total emissions from the refrigeration and air-conditioning sectors. Direct emissions of climate gases are thus part of the following analysis.

Indirect emissions are due to energy consumption and contribute the other two thirds of total emissions. They depend heavily on the source of electricity and on how much CO₂ is emitted during energy generation and are therefore different for each country, depending on its energy mix (GIC 2015). In any case, given the increasing share of refrigeration and air-conditioning products among the total energy consumed, and considering the relatively high percentage of non-renewable energies in most countries of Sub-Saharan Africa, increased efficiency of these appliances can also significantly lower indirect CO₂ emissions in Sub-Saharan Africa.

Increasing demand in Sub-Saharan Africa

The demand for refrigeration and air-conditioning equipment is driven by the need for cooling. Demand for cooling in Sub-Saharan Africa will rise substantially, due not only to the increasing presence of cooling equipment in Sub-Saharan African households and businesses, but also to the projected increase of average ambient temperatures in Sub-Saharan Africa and to the future increase in the number of very hot days due to climate change.

Domestic refrigeration is the appliance sub-sector with the highest number of units. The global stock is estimated to be approaching 1.5 billion units, with 100 million units produced annually. The refrigerator is the most popular

household appliance in use in developed countries, and is one of the first appliances to be bought once an electricity connection becomes available. Thus, the number of refrigerators in use in developing and emerging economies is projected to double to just under two billion in the next 15 years (U4E 2017a). Its market penetration in Sub-Saharan Africa will thus most probably follow the rising curve of the region's electrification.

49 million refrigerators, refrigerator-freezers and freezers are in use in Sub-Saharan Africa.⁶ The average annual consumption of all these cold appliances amounts to about 416 kWh; this is quite low considering the high temperatures and poor efficiencies of these models. Nevertheless, together, they account for almost 24% of the total domestic electricity consumption and cause annual greenhouse gas emissions of 16 million tons of CO₂ equivalent (bigEE 2012a).

Air-conditioning in buildings is the fastest-growing of all the refrigeration and air-conditioning sub-sectors, especially as more and more people in developing and transitioning countries in warm climates can afford air-conditioning in their homes. In some cities, air-conditioning is already responsible for up to 40% of all electricity consumption. In 2015, room air-conditioning accounted for approximately 20% of the residential electricity demand in 150 developing and emerging countries.⁷ Air-conditioning makes up a significant portion of household energy demand, in particular in regions with hot climates (which is the case for Sub-Saharan Africa) where periods of high use correlate with peak demand. Such peak power demand from air-conditioning appliances can threaten the stability of electrical grids (U4E 2017b), which are particularly fragile in Sub-Saharan Africa.

2.2.4. Demand for quality infrastructure services in Sub-Saharan Africa for the sub-sectors identified

In the following, quality infrastructure services for market surveillance, installation and maintenance for both re-

frigeration and air-conditioning appliances are analysed. Where a specific aspect only applies to one of the two categories, it is mentioned in the text.

Metrology

The uncertainty of the services provided by all organizations involved in the services mentioned above depends on the calibration of the equipment used for these tasks. Additionally, it is crucial that traceability be established for all services provided. Traceable services with low uncertainty create the basis for the international trade of refrigeration and air-conditioning appliances as well as for effective conformity assessment, installation and maintenance.

At present, some countries in Sub-Saharan Africa lack relevant metrological services. In other countries, existing services do not have the necessary quality management (especially intercomparisons, calibration of the equipment and accredited quality management systems or the registration of calibration and measurement capabilities) or are not sufficiently used by the sector.

Thus, in all countries in Sub-Saharan Africa, it is crucial that testing and secondary calibration laboratories service providers who use testing equipment and inspection bodies are guaranteed access to calibrations and intercomparisons. In countries where basic metrological services in the areas of temperature and electricity are already offered, it is important that the national metrology institutes continuously improve the quality of these services. Furthermore, in many cases, the use of metrological services for energy efficiency measures must be increased – for example, by fostering awareness and information in the sector and by considering metrological services in energy efficiency policies.

In countries where basic metrological services cannot be provided at present, cooperation with other national metrology institutes in the region could be fostered. However, as energy efficiency measures become increasingly important for the reduction of greenhouse gas emissions and energy consumption in Sub-Saharan Africa, the development of the basic services required should be considered by the national metrology institutes, reducing cost and turnaround time for the sector. The development of such services should always be focussed on the specific projected demand.

⁶ When referring to cooling and freezing appliances, we consider domestic, commercial and professional cooling and freezing appliances, the former consisting of domestic refrigerators, freezers and combinations thereof.

⁷ Since data availability for Sub-Saharan Africa is a considerable problem, we assume a similar share in residential energy use in Sub-Saharan Africa.

At present, specific metrological services are only offered by the most advanced national metrology institutes in the region – for example, the calibration of equipment for tests of low power consumption used in stand-by mode. As the demand for these specific services will probably continue to remain relatively low in the future, it will be sufficient for only a few specialized national metrology institutes to offer these services in Sub-Saharan Africa. It is important that the development of basic as well as specialized metrological services required by the energy efficiency sector be coordinated by the regional and sub-regional metrology networks.

Standardization

Standards for increasing the efficiency of refrigeration and air-conditioning appliances in Sub-Saharan Africa are mainly needed in the following areas:

Appliance testing standards and competence for testing and calibration

Standards in this area define common criteria for refrigeration and air-conditioning appliances. They are required in order to ensure that information on energy efficiency is reliable and comparable. This information creates the basis for effective market surveillance and maintenance of the equipment. The following international standards are the most relevant in this area:

- **IEC 62552:2015 – Household refrigeration appliances – Characteristics and test methods.** The standard has several parts and can be used worldwide for policy and sampling purposes. It is favoured in many countries because it includes flexibility for adaptation of results to suit local climate and internal storage temperatures while ensuring comparability of results between economies (U4E 2017).
- **ISO 5151:2017 – Non-ducted air conditioners and heat pumps – Testing and rating for performance.** The most common test standard worldwide for measuring the cooling capacity and efficiency of alternating currents (ACs), based on two testing methods that display differences related to accuracy and the cost of the laboratory setup (more details below under “testing”).
- **ISO/IEC 17025:2005 – General requirements for the competence of testing and calibration laboratories.** The main international standard for testing (and calibration) laboratories.

The three international ISO/IEC standards mentioned above define basic criteria which should be available for conformity assessment organizations in Sub-Saharan Africa. In many countries in the region, they have already been adopted to national standards. Adoption at a national level should be envisaged where this has not yet taken place in order to facilitate access to the sector and to allow for a national referencing – for example, in energy-label regulations.

Standards for services: Installation and maintenance

Both direct and indirect emissions of refrigeration and air-conditioning appliances could be greatly reduced by appropriate maintenance practices. Direct greenhouse gas emissions in both product groups arise from leakages and venting of the refrigerant circuit prior to repair, as well as during the repair activity due to improper servicing practices. Recovery of the refrigerant is not a common practice. The refrigerant is often vented during servicing or repairs before the appliances are completely recharged. There may be huge savings in refrigerant consumption if proper recovery is carried out by the service technicians. Often, the system is merely topped up with refrigerant without proper leak detection, and will therefore continue to leak. “Good service practices” include recovery of refrigerant, leak and pressure testing and replacement of inoperative spare parts. These practices increase the operative life of the equipment and benefit the environment (GIZ 2013).

In Sub-Saharan Africa, the repair of domestic and small commercial refrigeration and air-conditioning appliances represents an important part of the income of service providers in this field. Most of the companies are small and operated by the owners themselves with a minimal staff of technicians and assistants. Service personnel are normally not well-trained; knowledge is gained by taking a “learning by doing” approach (GIZ 2011).

A specific issue related to air conditioning is the correct installation of the systems. Incorrect installation can lead to increased energy consumption, poor air circulation, and maintenance problems. Studies have demonstrated that the improper installation of air-conditioning appliances reduces their capacity and efficiency by more than 20%. In fact, appropriate installation of air-conditioning appliances is an important practice in order to maintain an economical, efficient and comfortable cooling system (GIZ 2013).

Better information and training of installation and maintenance personnel for refrigeration and air-conditioning appliances would result in a reduction of direct greenhouse gas emissions. Additionally, better maintenance would lead to increased energy efficiency of the equipment, resulting in lower indirect greenhouse gas emissions (GCI 2015).

In the area of installation and maintenance, a standard from the United States, “180-2012 – Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems” (ANSI/ASHRAE/ACCA approved), exists for commercial heating, ventilation and air conditioning. It defines criteria for the inspection of the correct installation as well as appropriate maintenance of the systems. This standard could be adapted or adopted at a regional or national level. No standard for the servicing of domestic heating, ventilation and air conditioning systems could be identified in the scope of this study. The development of a guidance document for the maintenance of domestic refrigeration and air-conditioning appliances could promote good practices in this area.

Additionally, national or regional standards on the competences of installation and maintenance personnel could create the basis for certification in this area. Standards and certification schemes for installation and maintenance technicians already exist in different developing and emerging countries such as India.

Testing, certification and inspection

Testing according to international standards is required for effective market surveillance and provides the information needed for certification and inspection schemes. As stated above, the most common test standard for household refrigeration appliances is IEC 62552:2015. It requires two tests at ambient temperatures of 16 °C and 32 °C. These temperatures have to be kept steady for the duration of the tests. This means that a climate chamber is required, which entails a significant investment.

ISO 5151 is the most common international standard for testing the cooling capacity and efficiency of air conditioners. It specifies how to measure the cooling capacity and efficiency of air-conditioning appliances using stipulated testing conditions. Testing procedures are based on two testing methods to measure the energy performance of air conditioners: the calorimeter room method and the indoor air enthalpy method. The calorimeter room meth-

od offers high accuracy at a higher testing time and cost of tests, while the indoor air enthalpy method requires a less expensive laboratory with shorter testing times but lower accuracy. The indoor air enthalpy method is sufficiently accurate for large-capacity air-conditioning appliances but not enough for small capacity units (U4E 2017b).

For the testing of air-conditioning appliances with a standby function, specific equipment for analysing very low power inputs is needed, requiring additional investment. As the investment required for developing testing laboratories for both refrigeration and air-conditioning appliances is substantial, and as the demand for such services is limited in most countries of Sub-Saharan Africa at present, it seems recommendable to promote the development of specialized testing laboratories which may serve as a reference at a regional level. Existing initiatives to support cooperation in the area of energy efficiency could be used to coordinate the development of such laboratories. For example, the Economic Community of West African States (ECOWAS) supports cooperation in the area of energy efficiency and renewable energy.

Product certification

Schemes for certification in the country of origin based on specific national standards or regulations are applied in several countries in Sub-Saharan Africa such as Kenya and Nigeria. Such certifications are offered by international certification bodies. Nigeria, for example, operates a system to certify that products to be imported into the country are in conformity with the applicable Nigerian standards and technical regulations before shipment. The system is mandatory for nearly all imported goods, including refrigeration and air-conditioning appliances. Under that regime, imports are required to undergo verification and testing in the country of origin. Based on this, a specific certificate is issued. The conformity assessment elements undertaken include physical inspection prior to shipment, sampling, testing and analysis in accredited laboratories, auditing of production processes and systems, checking the conformity of documents with regulations and overall assessment of conformity to standards. A similar system is applied in Kenya.

It must be considered that such mandatory systems based on specific national standards or regulations result in barriers to trade, as exporting companies have to certify their products based on specific national requirements. For this reason, multilateral certification systems based on

international standards can be seen as a more appropriate option. For electrical appliances, including refrigeration and air conditioning, the IEC System for Conformity Assessment Schemes for Electrotechnical Equipment and Components (IECEE) is a multilateral certification system based on international IEC standards. Member states of the system use the principle of mutual recognition of test results to obtain a product certification which is valid in other member countries around the world (IECEE 2017).

Most refrigeration equipment imported into Sub-Saharan Africa originates from countries which are part of the IEC system (i.e., China and OECD countries). Their labels, such as Energy Star and the European Union's energy labels for refrigeration and air-conditioning appliances, fall under the agreement. Test certificates and test reports issued are commonly accepted by national authorities, retailers, buyers and vendors. In Sub-Saharan Africa, Kenya, Nigeria and South Africa are members of the IEC System for Conformity Assessment Schemes for Electrotechnical Equipment and Components. However, non-members can also accept tests and certifications carried out under the system. It thus seems important to promote the participation of further countries in Sub-Saharan Africa in the system, either by becoming member countries or via recognition of tests and certification in order to facilitate the trade of energy-efficient products.

Certification of services

Improper installation and maintenance of refrigeration and air-conditioning appliances can result in environmental and safety risks. At the same time, existing refrigeration systems are kept running beyond their economic lifetime, resulting in increased demand for servicing. For this reason, the certification of installation and maintenance personnel is important. In this context, it must be considered that most companies offering such services in Sub-Saharan Africa cannot afford to invest in training courses or reliable service equipment (GIZ 2011). National training and awareness raising programmes are important in order to increase knowledge on appropriate installation and maintenance practices, based for example on national or regional guidance documents (see above). Certification of personnel could be promoted in Sub-Saharan Africa, especially for commercial refrigeration and air-conditioning systems as well as for new buildings.

Market surveillance

To avoid unnecessary obstacles to trade, controls at the point of entry should be limited to formal checks in customs procedures. Product certificates facilitate these formal checks.

Market surveillance of refrigeration and air-conditioning appliances is especially important in Sub-Saharan Africa considering the high percentage of imported sub-standard and used products. Market surveillance is also required if "certification in country of origin" schemes are applied, as counterfeit certificates and insufficient customs procedures must be identified. The minimum approach to be applied comprises inspections of appliances in shops and at the retailer's business based on marks and labels on the appliances as well as supporting documentation. Such inspections should be combined with non-destructive testing to allow the real (energy) performance to be compared with the indication in certificates and product documents. Tests can be performed either for samples of marketed products or upon complaints by customers. For the countries of Sub-Saharan Africa, this means that testing services are needed which are in line with relevant international standards; this will require substantial investments. As stated above, the development of specialized laboratories in the region could help to cover these needs, even considering the expenditure required for sending the appliances for testing across borders.

Accreditation

Accreditation services relevant for refrigeration and air-conditioning appliances include accreditation of testing and calibration laboratories, certification and inspection bodies. Considering that refrigeration and air-conditioning appliances in Sub-Saharan Africa are mainly imported, internationally recognized accreditation is especially important for ensuring the technical competence of the providers of these services. Accreditation is needed to ensure the international recognition of certificates and the legal validity of inspection and testing services (for example, in lawsuits).

In many countries of Sub-Saharan Africa, the accreditation services needed do not exist at present. Cooperation agreements with internationally recognized bodies which exist in the region may lower the accreditation costs and the accessibility for clients. The cooperation potential in this context should be identified on a regional level.

Regulation/transversal aspects

It is important to provide information and raise awareness concerning the need for a systematic and holistic development of quality infrastructure services which are necessary in order to increase the energy efficiency of refrigeration and air-conditioning appliances. At present, in many countries of Sub-Saharan Africa, policies and concrete measures are being defined to foster energy efficiency, although quality infrastructure is often not considered sufficiently. For this reason, information and awareness-raising activities are needed in order to include quality aspects in relevant policies and regulations and increase the sector's understanding of the benefits of quality infrastructure services. Such activities have to involve

all relevant organizations of quality infrastructure, as it is fundamental that services be developed systematically while considering the concrete needs of the sector.

In the area of regulation, quality requirements for air-conditioning systems may be defined especially for new buildings (bigEE 2015, see also Annex 2). The certification of installation and maintenance personnel could be required especially for systems in the commercial sector.

Quality requirements for refrigeration and air-conditioning appliances should also be included in public tenders. In order to reduce energy consumption in the public sector, Sub-Saharan African governments could make efforts

Quality infrastructure services/value chain	Quality challenges	Metrology	Standardization	
Maintenance, repair and monitoring	<ul style="list-style-type: none"> ■ Prevention of direct and indirect greenhouse gas emissions ■ Performance monitoring (air conditioning: detecting heat losses) 	<ul style="list-style-type: none"> ■ Calibration of testing devices and equipment: Development of basic metrological services at a national level (e.g. in the areas of temperature and electricity) and specialized services (e.g. calibration of equipment for tests of low power consumption) regionally 	<ul style="list-style-type: none"> ■ Adoption of relevant international standards for the testing of appliances ■ Adoption/adaptation of standards for installation and maintenance ■ Development of guidance documents for installation and maintenance ■ Development of standards on the technical competence of personnel for installation and maintenance 	
Installation	<ul style="list-style-type: none"> ■ Prevention of greenhouse gas emissions 			
Market surveillance	<ul style="list-style-type: none"> ■ Fitness for purpose (no standard products) and performance of imported products 			

Table 3: Quality issues and necessary services of quality infrastructure along the value chains of refrigeration and air-conditioning appliances

to introduce “green public procurement” criteria for the procurement of refrigeration and air-conditioning appliances, based on existing energy efficiency schemes. Strong arguments for such policies are their contributions to the national climate objectives and the relatively rapid return on investment in the case of more efficient equipment.

In the following table, most points apply to both refrigeration and air-conditioning devices. Where an issue is applicable only or mostly to one of them, it is marked with “R” for refrigeration or with “AC” for air-conditioning equipment.

	Testing	Certification	Inspection	Accreditation	Regulation/ transversal aspects
	<ul style="list-style-type: none"> ■ Set-up of specialized testing laboratories which provide tests based on the relevant international standards on a regional or national level 	<ul style="list-style-type: none"> ■ Certification of personnel for maintenance and installation 	<ul style="list-style-type: none"> ■ Inspections (of air-conditioning and professional/commercial refrigerating installations) ■ Inspections of appliances in shops and at retailer locations ■ Pre-shipment verification ■ Controls at point of entry 	<ul style="list-style-type: none"> ■ Accreditation of laboratories (testing/calibration), certification and inspection bodies ■ Cooperation agreements with internationally recognized accreditation bodies in the region 	<ul style="list-style-type: none"> ■ Awareness raising and information programmes on the importance of quality infrastructure for energy efficiency ■ Update/extension or introduction of Minimum Energy Performance Standards and labelling programmes ■ Implementation of programs for professional qualifications and vocational training (of servicing technicians)
		<ul style="list-style-type: none"> ■ Product certification and labelling based on international or national standards ■ Mutual recognition of tests and certificates 			<ul style="list-style-type: none"> ■ Definition of technical and quality criteria for the commissioning (of professional/commercial) installations ■ Inclusion of technical and quality criteria into procurement procedures ■ Capacity building of installers

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2.3. Meteorology

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2.3.1. Current trends in the sector in times of climate change (global and regional)

Meteorology is the science of physical and chemical processes in the atmosphere and includes the well-known subjects of weather forecasting and climatology.⁸ Meteorology delivers climate data which form the primary resource for climate monitoring. It furthermore serves as a provider of climate information which can be used in decision-making processes (so-called climate services). Such decisions have to be taken in other sectors (e.g. agriculture, water, disaster risk management and politics in general) which are facing the challenge of mitigating adverse impacts of climate change and looking for approaches to adapt to it. The relevance of climate services, therefore, cannot be overestimated.

Climate data depend on reliable observations of variability and long-term changes in the atmosphere (IPCC 2013:20). The challenge in many developing countries in Sub-Saharan Africa is that climate data are often of poor quality. Where this is the case, such data will either not be used or, if they are used, the climate services will be of poor quality. If the services are of low quality, they will not be trusted and thus not be used. If neither climate services nor data are used, there will be no incentive to increase quality. Therefore, the further development of climate observations and services is trapped in a vicious cycle.

The quality of climate services depends, among other things, on well-calibrated instruments as well as standardized routines for processing and reporting climate data. This already indicates a high relevance of an adequate quality infrastructure for the products and services of meteorology.

⁸ In this report, the term 'meteorology' is used for observation and documentation of the climate. The distinction between weather and climate is of particular importance: The expression 'climate is what you expect and weather is what you get' (Heinlein 1973) is a good narrative to explain the difference. Weather is the actual state of the atmosphere, while climate describes a) the average conditions of the atmosphere and b) a set of typical climate conditions describing the diversity of atmospheric conditions which is typical for a specific geographic area (e.g. maritime climate, tropical climate).

At the same time, the final quality of climate data also largely depends on its providers and supporting elements, which will be described in the following section: the relevant institutions and infrastructure in the meteorological sector.

World Meteorological Organization

In the meteorological sector, the World Meteorological Organization (WMO) is in charge of the following tasks related to quality infrastructure (WMO 2017a):

- The establishment of networks of observational stations to provide weather, climate and water-related data;
- The establishment and maintenance of data management centres and telecommunication systems for the provision and rapid exchange of weather, climate and water-related data;
- The creation of standards for observation and monitoring to ensure adequate uniformity in the practices and procedures employed worldwide, and thus to ascertain the homogeneity of data and statistics.

The organization represents 185 member states and six member territories. The states and territories are represented by the heads of the respective national meteorological and hydrological services. These heads represent their countries, but not their institutions. As a technical agency of the United Nations, the WMO rules in its decision bodies (Congress and Executive Council) only by consensus. The enforcement of regulations and rules is the matter of the member states solely. The WMO sets its agenda via inter-ministerial alignment on a national level and then by means of channelling to the organization via the heads of the respective national service. To improve quality infrastructure for climate change adaptation, both globally and in Sub-Saharan Africa, it must be in accordance with the regulations, standards and practices of the WMO.

Weather systems (e.g. cold or warm fronts) normally span across country borders; meteorology works on a horizontal scale of at least 1,000 km. The global synoptic network which exists today takes simultaneous observations every three hours, without taking due account of country borders. It is therefore necessary to ensure the comparability of the observations in space and time. The WMO's "Observing Systems Capability Analysis and Review Tool" (OSCAR), which is a part of the organization's Integrated

Global Observing System (WIGOS), compiles the observation requirements for many meteorological variables concerning different application areas.⁹

World Meteorological Organization Regulations and Standards

The WMO issues *Technical Regulations*, *Meteorological Standards*, *Recommended Practices* and *Guides* for its members. Members are required to follow or implement standard practices and procedures. Furthermore, they are urged to comply with recommended practices and are invited to follow or implement the published guides.

Technical Regulations are complemented by separately published annexes, which are called *Manuals*. Formally, standards are binding, but their implementation and enforcement remain on a national level. Effectively, all WMO publications are voluntary.

Quality management within the system of the World Meteorological Organization

The WMO decided to work towards a quality management framework for national meteorological services at the 14th World Meteorological Congress (WMO 2013:2). This framework mainly addresses the quality management aspects of the ISO 9000 family.

Another relevant aspect concerning climate change is the accuracy of observations for climate monitoring. This falls under the responsibility of the Commission for Instruments and Methods of Observation (CIMO). It was set up by the International Meteorological Organization to “ensure the accuracy of weather observation by facilitating the creation of international standards and, thus, the compatibility of measurements” (WMO 2017b).

The Commission for Instruments and Methods of Observation also publishes the *Guide to Meteorological Instruments and Methods of Observation* (WMO 2014). This is the most important guidance document regarding the quality management of meteorological observations. The manual specifies the WMO Standards¹⁰ for observations

of meteorological variables in detail and includes the different types of errors. Furthermore, the Guide describes testing routines for sensors as well as site requirements for meteorological stations.

As all WMO publications are voluntary, the implementation of the quality management measures defined by the organization depends on factors such as political will, status of organizational development and the training level of the personnel. This also applies for the traceability of the meteorological information generated: “It is up to each National Meteorological and Hydrological Service to choose the most suitable approach for its traceability assurance, but ensuring the metrological traceability of all measurement results is strongly recommended” (WMO n.d.). In many developing economies, not all quality management measures defined by the organization are implemented. As a result, the reliability and traceability of the information generated is not always ensured.¹¹

Regional Instrument Centres (RICs)

The Regional Associations (RAs) of the WMO have designated Regional Instrument Centres to support the National Meteorological Services with calibration services for their instruments. It is recommended that Regional Instrument Centres have the following capabilities (WMO 2014:27–29, selection of the relevant issues by the author):

- Calibration of meteorological and related environmental instruments;
- Maintenance of a set of meteorological standard instruments and establishment of the compliance of its own measurement standards and measuring instruments with the SI;
- Participation in, or organization of, inter-laboratory comparisons of standard calibration instruments and methods;
- Application, where possible, of international standards relevant for calibration laboratories, such as ISO/IEC 17025;
- Development of individual quality assurance procedures.

⁹ The following web page provides meteorological benchmarks for uncertainty, stability and spatial and temporal resolution of observations: <https://www.wmo-sat.info/oscar/observingrequirements>.

¹⁰ In line with WMO 2011: 2 “the word “standard” will be used as follows: (a) when it refers to a formal published document such as an ISO International Standard, it will be written as Standard; (b) when it refers to specific WMO manuals, procedures and practices, it will be written as WMO Standard.”

¹¹ For this reason, possible different approaches are being discussed in the organisation. One option is to move from WMO Standards (“best practices”), towards a “known practices” approach. The observational data would be complemented with more procedural information and metadata. Meteorologists could then evaluate the data considering the metadata (pers. Communication F. Teichert, WMO/DWD, 27.07.2017).

A distinction is made between Regional Instrument Centres which have ‘full’ and those which have ‘basic’ capabilities and functions, as defined in their respective Terms of Reference. ‘Full’ Regional Instrument Centres are distinguished by a) a higher number of meteorological standard instruments, b) the participation in intercomparisons and c) the organization of regional workshops on meteorological and related environmental instruments.

Two Regional Instrument Centres are operated in Sub-Saharan Africa: one in Nairobi (Kenya) and one in Gaborone (Botswana). The WMO does not publish updated information on the current status of the Regional Instrument Centres. The one in Nairobi was visited within the framework of this study. Further details are included in section 3.1 on Kenya.

Apart from National Meteorological Services and the WMO, other public institutions operate weather stations and collect climate-relevant data – in particular, agricultural and hydrological services which are often carried out on the sub-national scale. Such services do not normally apply documents of the WMO and rarely exchange data. The WMO Observing Systems Capability Analysis and Review Tool can integrate such external observation systems (Barrell 2013). Furthermore, private-sector companies are increasingly entering the meteorological market by offering weather forecasts, climate services and other meteorological products. If the different organizations complied with identical traceable standards, observations would become comparable and the observation density and quality would increase noticeably.

Innovations in Meteorology

In the last 30 years, digitalization has promoted the automatization of weather stations and real-time data transmission. This has provided a new opportunity for observing climate variables at a high logging frequency at remote locations. Today, many National Meteorological Services in industrial countries have equipped their meteorological observation networks with automated weather stations. In Sub-Saharan Africa, this process is still ongoing and can also be used to increase the weather station density where necessary. Operation and maintenance of the stations are a constant challenge (see further explanations below).

Currently, a wave of disruptive innovations is occurring. Sensors are built into devices, vehicles and infrastructure

(such as houses and wind turbines) for very different and usually specific purposes. The operator, usually a private enterprise, collects data which contain meteorological information. For example, the rain sensor in vehicles is commonly used to start the windscreen wipers automatically. Together with the location data of the vehicle, operating wipers can be used to compute the area covered by rainfall. This addresses the lack of information on the spatial extent of rainfall events. The number of cars providing the information compensates for the fact that the sensor of an individual car does not provide a precise value. Similarly, temperature sensors in mobile phones which measure the temperature of the battery can also be used to provide information about the outdoor temperature (Open Signal 2013). Another interesting example is the attempt to analyze microwave signals to deduce information about rain (Walsh 2013).

All these technological trends are still in an early experimental state, and some may never develop into a mature solution. Furthermore, the following aspects must be considered concerning these new approaches: (a) The observations generated by the new technologies also have to be corroborated by in-situ observations from reliable meteorological stations; and (b) these observations come from new data providers who are not currently linked to the National Meteorological Services. At present, only very few cases of cooperation between National Meteorological Services and private enterprises exist.

Despite these considerations, these innovative approaches offer potential (e.g. for short term warnings) where a low density of meteorological stations still prevails. For Sub-Saharan Africa, these innovative approaches can trigger solutions which do not appear useful in countries with more developed meteorological systems.

Sub-Saharan Africa

The overall density of weather stations in Sub-Saharan Africa is insufficient. Moreover, existing weather stations are often not in a proper location (for example, too close to buildings) or appropriately maintained. Examples of improper maintenance found in Sub-Saharan Africa include the failure of equipment which is not repaired or replaced on time, failure to clean the equipment and a lack of data transmission due to the expiration of SIM cards. Many weather stations are located in remote and difficult-to-access areas. At the same time, most National Meteorological Services in Sub-Saharan Africa have a very

limited budget and limited personnel. Often, they do not have sufficient internal resources for the maintenance of the weather stations; however, past approaches in which the local population was involved in the maintenance of the stations have also failed in many cases. Additionally, the meteorological equipment is often stolen.

Scarce weather stations with lacking maintenance, together with gaps in the implementation of the quality management measures defined by the WMO, lead to insufficient meteorological information in Sub-Saharan Africa. In the context of climate change, this situation is increasingly problematic, as meteorological information is needed for accurate weather services and long-term climate monitoring. Monitoring data and weather services provide the basis for planning and decision making – for example, for impact and vulnerability mapping, the design of infrastructure such as bridges or hydropower installations and early warning systems.

Several initiatives in Africa support the creation of more meteorological information and increase its reliability. The African Ministerial Conference on Meteorology issued an Integrated African Strategy on Meteorology (Weather and Climate Services). This strategy explicitly states that ISO certification should be achieved for quality management systems, competencies of personnel should meet international standards and the equipment should have calibration certificates (AMCOMET, 2013). However, follow-up documents do not show effective progress.

Non-governmental organizations such as the Trans-African Hydro-Meteorological Observatory plan to install a greater number of weather stations. The observatory proposes the installation of 20,000 weather stations in Africa (see website: <http://tahmo.org/>). Similarly, the Weather for All Initiative, a public-private partnership, plans to establish a network of 5,000 weather stations (see website: <http://www.ghf-ge.org/wifa.php>).

The Uganda National Meteorological Authority (UNMA) has piloted an innovative approach, cooperating with mobile phone companies to equip transmission masts of the mobile phone network with meteorological instruments. The project titled Mobile Weather Alert in the Lake Victoria Region (WMO 2017c) provided warnings to fishers on Lake Victoria. However, the project was closed in 2016 due to insufficient funding.

Another innovative initiative installs low-cost weather stations in Zambia (Hosansky & Snider 2016). Scientists from the National Center for Atmospheric Research (NCAR) and the University Corporation for Atmospheric Research (UCAR) developed a low-cost weather station largely built from 3D-printed parts which can easily be replaced. This reduces the costs from between USD 10,000 and USD 20,000 for a conventional weather station to USD 300 for a 3D-printed station.

2.3.2. Significance of quality infrastructure services

For the significance of quality infrastructure, it is important to consider the portfolio of climate services and their focus on an ex-ante analysis. Figure 2 shows seamless weather and climate services as a function of the lead time. Weather warnings have a lead time of hours; weather forecasts look from about one week up to 10 days ahead. The weather forecast is constrained by uncertainty about the future development of the weather, which increases with the lead time. It should be noted that the acceptance of climate services for end users relies to a large extent on the reliability of weather forecasts. As climate change will result in an increasing number of extreme events (especially droughts and floods) in Africa (Niang et al. 2014), the importance of weather warnings and reliable forecasts will increase.

Climate services for many sectors are based on the statistical analysis of time series. In most cases, climate variables over longer time series are combined with appropriate sector-specific information. The results of this analysis are used, for example, for (1) design depth of precipitation for flood control, (2) reservoir design for hydropower or irrigation, (3) test reference years (TRY) for heating/cooling and insulation of buildings (DWD 2017) and (4) climatic suitability for specific crop types (FAO 2017). The WMO has defined normal periods of 30 years to provide consistent and comparable data (1960–1990, 1991–2020). For climate change, the non-stationary condition is prevalent, and an extrapolating trend analysis has to be considered in order to derive appropriate predictions on a local scale. The local scale is most relevant for the planning of adaptation measures (for example, the design of water reservoirs).

In all cases, **reliable time series of observed climate variables are the foundation for climate services**. Quality infrastructure services which ensure the high accuracy and reliability of in-situ observations and the high quality of subsequent (standardized) data processing directly impact the quality of many weather and climate services. Newer “remote sensing” approaches (by means of satellites or weather radar) also need “ground truth” verification based on in-situ observations.

This emphasizes the necessity of systematic quality management at all stages of the process – from meteorological observations and data processing to data storage in central databases as well as data access for the respective users – to ensure the reliability of observational data and long-term time series.

Quality infrastructure provides the services required for systematic quality management of meteorological information. The contributions of the components of quality infrastructure may be summarized as follows:

- **Metrology:** Provides traceability, calibrations and intercomparisons required for accurate meteorological observations. These services are especially important for Regional Instrument Centres and National Meteorological Services, but also for other organizations operating weather stations.
- **Standardization:** Provides commonly agreed criteria for systems, processes and methods in the sector, thus creating the basis for comparable and reliable information. In the meteorology sector, the documents published by the WMO (see above) are especially relevant, but ISO standards such as ISO 9001 are applied as well.
- **Testing, certification and inspection:** Are necessary in order to assess conformity of the relevant equipment, systems and personnel via quality criteria. The systematic application of certification schemes could be especially effective for improving the efficiency of purchasing processes, fostering quality management in meteorological organizations and confirming the competence of technical personnel.
- **Accreditation:** May ensure technical competence, especially that of meteorology organizations and the relevant metrology laboratories. The accreditation of the Regional Instrument Centres could contribute to providing traceable and reliable calibration services to the National Meteorological Services.

Seamless Climate Services

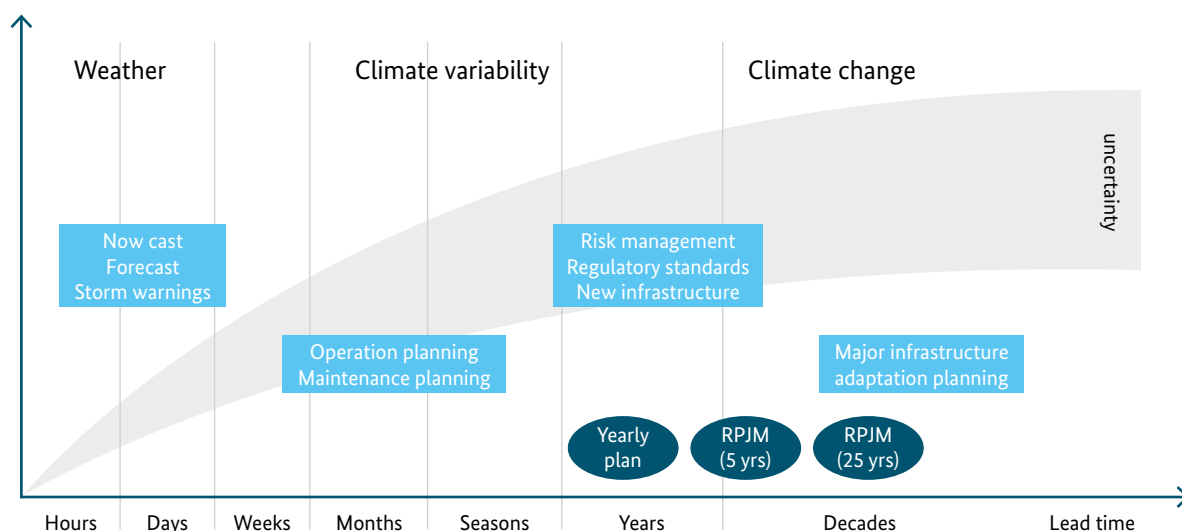


Figure 2: Seamless climate services (Rappold 2015)

2.3.3. Identification of sub-sectors relevant in Sub-Saharan Africa

The selection of sub-sectors to be considered in this study is based on an evaluation of their relevance in the context of climate change, the relevance of quality infrastructure services for the sub-sector and the relevance of the sub-sector in Sub-Saharan Africa.

Given the definition of meteorology in the context of this report, the following sub-sectors emerge:

- In-situ observations
- Data processing and reporting
- Remote observations

In-situ observations (weather and climate stations)

In situ observations of weather stations are the backbone of climate change documentation but also the key ingredient in short-term forecasts and warnings. Both will become increasingly important in the context of climate change in Sub-Saharan Africa. They are the reference for all derived information and many other climate data products and services (e.g. remote sensing observations, statistical indices such as the indices of the Expert Team on Climate Change Detection and Indices, ETCCDI). They are also used for quality comparisons and bias adjustments of numerical climate models (climate models are constructed independently of observational data). Observations in Sub-Saharan Africa are scarce, are scattered over different institutions and are often of low quality. Because observation standards from different institutions are unavailable, such observations are comparable only to a very limited extent. Quality infrastructure services are of key importance when addressing these issues. The relevance of in-situ observations is ranked high for all three criteria.

Data processing and reporting

As mentioned above, WMO standards exist for data processing and quality control. However, implementation of these standards by the National Meteorological Services differs from organization to organization. Other actors operate weather stations, but in some cases do not consider WMO standards at all (for example, in the agricultural or private sector). For this reason, comparability and coherence of climate data are not always ensured, and data quality is controlled based on differing models. These topics are of high relevance for climate change in Sub-Saharan Africa. The possible contribution of quality

infrastructure, however, is not substantial, as it is mainly limited to the area of standardization.

Remote observations (satellite)

Remote observations are made using technologies which produce consistent information over a spatial area. This is a major advantage compared to point measurements and addresses the poor spatial data coverage in Sub-Saharan Africa. With the progress of the “European Earth Observation Programme – Copernicus” and other programmes, remote sensing data has become accessible. Nevertheless, the satellites themselves belong to space consortiums. Cloud-based technologies¹² replace the extensive IT infrastructure needed in the past. Access to remote sensing data and services now only requires regular computers with decent internet access. This results in Sub-Saharan Africa being highly relevant in the context of climate change. However, the possible contributions of quality infrastructure are very limited. Therefore, remote observations are not considered further in this study.

2.3.4. Demand for quality infrastructure services in Sub-Saharan Africa for the sub-sectors identified

Currently, the demand for quality infrastructure services in the meteorological sector in Sub-Saharan Africa is very limited, as it is in other parts of the world. This is caused by the fact that the WMO and National Meteorological Services have developed their own internal approaches to quality management, mainly without making use of external services.

In the following section, for the sub-sectors of in-situ observations as well as data processing and reporting, the current demand for and possible contribution of quality infrastructure are described more in detail.

Metrology

At present, most calibrations of the equipment used in weather stations are coordinated between the meteorological organizations. The National Meteorological Services calibrate most of their equipment in the WMO Regional Instrument Centres.

¹² For example: <https://earthengine.google.com> and the EU Copernicus programme and its national implementations such as <https://code-de.org>

There are two Regional Instrument Centres in Sub-Saharan Africa: one in Nairobi, Kenya and one in Gaborone, Botswana. Based on a visit to the centre in Kenya and the assumption that the situation in Botswana is similar, it can be said that there is substantial potential for improvement of calibrations and intercomparisons. The Regional Instrument Centre in Kenya serves as a calibration laboratory for the weather stations in East Africa (Kenya, Tanzania, Uganda, Ruanda, Burundi, Ethiopia, Djibouti, Sudan, Eritrea). The laboratory offers calibration of the most common equipment used in weather stations (variables: temperature, humidity, rainfall, pressure and radiation, but not wind speed). At present, the equipment of the laboratory is not calibrated. Intercomparisons (e.g. with other meteorological calibration laboratories) have been realized in only two areas (pyranometers and thermometers).

At least for East Africa, it can be said that the current calibration practice may lead to unreliable data in the countries mentioned above. Traceability is not being ensured and the uncertainty of the data generated is not being calculated in the meteorological laboratories consulted in this study.

In this context, a significant opportunity for improvement can be seen in fostering the cooperation between the National Meteorological Services, the Regional Instrument Centres and the national metrology institutes to calibrate meteorological instruments. Considering the role of the Regional Instrument Centres as regional calibration laboratories for the National Meteorological Services, the calibration of their equipment is of particular importance. In many countries, the national metrology institutes can provide calibration services for basic equipment used in the weather stations – for example, for the variables of temperature and pressure.

An additional potential area of cooperation is the organization of intercomparisons. Intercomparisons of meteorological equipment are usually organized under the umbrella of the WMO. Apparently, not all National Meteorological Services and Regional Instrument Centres in Sub-Saharan Africa participate in these intercomparisons. The national metrology institutes could be involved in the organization of intercomparisons offered to National Meteorological Services as well as other organizations using meteorological equipment.

Finally, national metrology institutes could also support the meteorological organizations in the type approval of their equipment. Interview partners from Sub-Saharan Africa mentioned that, in some cases, new equipment procured does not comply with their requirements.

Standardization

As explained above, quality management of National Meteorological Services is mainly based on WMO Meteorological Standards, WMO Recommended Practices and WMO Guides. For meteorological organizations in Sub-Saharan Africa, the main challenge is in the application of the existing documents. In many National Meteorological Services in Sub-Saharan Africa, not all relevant documents are applied, mainly due to lacking training, appropriate structures and processes.

Additionally, the WMO suggests introducing quality management systems according to ISO 9001 to facilitate adequate processes for operation and maintenance. Of the meteorological organizations visited as part of this study, the Uganda National Meteorology Authority has an ISO 9001 certified quality management system in place; its Kenyan counterpart commented that, while such a system does not yet exist, plans are in place to implement this standard. A lack of systematic quality management results in questionable reliability of the meteorological information generated.

Another opportunity for improvement in the area of standardization can be seen in the processing of meteorological data. Kenya's National Meteorological Service in Nairobi operates the WMO Regional Transfer Hub (RTH) of the Global Telecommunication System (GTS) and collects the regional GTS data.¹³ There are WMO Standards and Guides for minimum data quality (see WMO (2010) Manual on the Global Data-processing and Forecasting System: Volume I - Global Aspects). The National Meteorological Services are responsible for implementing these standards. The implementation of WMO Standards varies, as different IT models are applied.

¹³ The WMO has operated the World Weather Watch (WWW) programme since 1963. It consists of three subordinated programmes: The Global Observing System (GOS) for making observations, the Global Telecommunication System (GTS) for the collection and distribution of observational data and the Global Data-processing and Forecasting System (GDPFS), which operates meteorological centres for quality-assured, processed data, analyses, and forecast products.

The opportunity to develop and apply unified software could be evaluated, for example as an open source application based on the WMO Standards.

Testing, certification and inspection

Certification schemes could ensure that management systems, meteorological equipment and staff conform to quality criteria. In the National Meteorological Services in Sub-Saharan Africa considered in this study, certification at present is not applied systematically for conformity assessment. In interviews, it was explained that, when purchasing essential equipment, the staff of the National Meteorological Services travel to the country of origin of the equipment to review whether the equipment complies with the criteria defined. This results in additional tasks for the very limited staff of the National Meteorological Services. An evaluation could be conducted as to whether an increased application and recognition of certifications in the country of origin could improve the efficiency and effectiveness of this procedure. A crucial factor for the reliability of observations is staff training. Specific personnel certification schemes which do not exist at present could help to ensure appropriate training levels. Inspection schemes based on the WMO Standards could help to ensure that the relevant standards are applied in the weather stations. The country studies indicate that such schemes are not being systematically applied.

Accreditation

Accreditation of the Regional Instrument Centre in Kenya has been proposed internally; however, to date, no concrete steps for the implementation of ISO 17025 have been realized.¹⁴ Considering the role of Regional Instrument Centres as regional calibration laboratories, their accreditation in Sub-Saharan Africa would be crucial in order to confirm their technical competence and implement a systematic quality management system in accordance with ISO 17025. Accreditation should be provided by an internationally recognized accreditation body, as the Regional Instrument Centres operate regionally. National accreditation bodies which are not internationally recognized at present (for example, in the case of Kenya – see section 3.1.) could be involved in this process – for example, via peer evaluations.

Regulation/transversal aspects

At present, opportunities for cooperation between meteorological organizations and the organizations of quality infrastructure are not systematically identified or used in Sub-Saharan Africa. The most important reasons for this seem to be of a political nature, as the WMO traditionally organizes its quality management internally without involving external organizations. In this context, to promote the use of quality infrastructure services in the sector, information and awareness-raising activities are required. Concrete cooperation projects in Sub-Saharan Africa – for example, on the calibration of the equipment in the Regional Instrument Centres – could serve as examples for other countries and regions as well. Such projects could include consultancy and capacity building on the use of quality infrastructure services in the meteorological sector and could be implemented in alliance with the German Weather Service (DWD), for example.

Additionally, current and potential demand in the meteorological sector for quality infrastructure services could also be identified by the regional and sub-regional quality infrastructure networks in Sub-Saharan Africa. In this context, future needs of emerging methods for the generation of meteorological information (see above) should also be considered.

¹⁴ No publicly available information could be found about the accreditation of the Regional Instrument Centre in Gaborone (Botswana).

Quality infrastructure services/ value chain	Quality challenges	Metrology	
Data processing and transmission	<ul style="list-style-type: none"> ■ Lacking maintenance. ■ Lacking application of WMO Standards. ■ No uniform IT implementations for data processing. 		
Maintenance	<ul style="list-style-type: none"> ■ Lacking calibration of equipment. ■ Maintenance cycles not applied. ■ Spare parts and replacement sensors for fast repair of the station not easily available. 	<ul style="list-style-type: none"> ■ (Re)calibration of equipment. ■ Organization of intercomparisons, involving national metrology institutes and meteorological calibration laboratories. 	
Operation	<ul style="list-style-type: none"> ■ Manual readings not properly done. ■ Non-‘certified’ data reduction and calculation methods. 		
Delivery/ transport/ installation	<ul style="list-style-type: none"> ■ Improper handling by service providers or staff damaging the equipment. ■ Initial calibration of sensors not correctly done. ■ Erroneous installation by untrained staff. ■ Metadata documentation insufficient. 	<ul style="list-style-type: none"> ■ (Re)calibration of sensors after transport. 	
Procurement	<ul style="list-style-type: none"> ■ Lack of capacity and knowledge result in improper procurement. ■ Quality standards not sufficiently defined (in the tender documents). ■ Quality of equipment does not match quality criteria defined. 	<ul style="list-style-type: none"> ■ Type approval of meteorological equipment. 	

Table 4: Quality issues and necessary services of quality infrastructure along the value chains of weather stations, data processing and transmission

	Standardization	Testing	Certification	Inspection	Accreditation	Regulation / transversal aspects
	<ul style="list-style-type: none"> ■ Creation of uniform software models (reference implementation) for real-time data processing based on the WMO Standards. 					<ul style="list-style-type: none"> ■ Evaluation of the possibility to apply uniform software models.
		<ul style="list-style-type: none"> ■ Testing of weather variables according to WMO Standards (CIMO). 	<ul style="list-style-type: none"> ■ Certification of maintenance staff. 	<ul style="list-style-type: none"> ■ Creation of inspection schemes for weather stations. 	<ul style="list-style-type: none"> ■ Accreditation of the Regional Instrument Centres according to ISO 17025 by internationally recognized accreditation bodies. 	<ul style="list-style-type: none"> ■ Awareness raising on the importance of and training on the application of relevant WMO documents and ISO 9000 in National Meteorological Services.
			<ul style="list-style-type: none"> ■ Certification of operational staff. ■ Certification of management systems in National Meteorological Services (ISO 9001). 			
			<ul style="list-style-type: none"> ■ Certification of staff installing the weather stations. 			<ul style="list-style-type: none"> ■ Training on installation according to CIMO Guide as WMO Standard (requires specified national guides).
			<ul style="list-style-type: none"> ■ Certification of devices in country of origin. 			<ul style="list-style-type: none"> ■ Training on procurement. ■ Clear definition of quality criteria in tendering processes.

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2.4. Agriculture

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2.4.1. Current trends in the sector in times of climate change (global and regional)

Agriculture contributes 15.6 % of Sub-Saharan Africa's Gross Domestic Product (GDP). In some countries such as Ethiopia and Burundi, agriculture accounts for more than 40 % of the economy (FAO 2015). Given the importance of the agricultural sector for regional economies and populations, adaptation of the agricultural sector to climate change is a key element for sustainable development in the region.

The agricultural sector provides a basis for social development, poverty reduction and livelihoods in the countries of the region, in particular of the rural population. 56 % of the regional workforce is employed in the sector. The poorest quintile has particularly high representation in this sector, producing mostly for autoconsumption and local markets (FAO 2015). At the same time, however, agroindustry for export markets is a thriving sector in some countries in Sub-Saharan Africa, providing an important source of income.

Agriculture therefore plays a major role for the achievement of several SDGs. The development of the sector is instrumental for achieving SDG 1 (eradication of poverty) and 2 (eradication of hunger) in the region. It also plays an important role in the achievement of SDG 6 (water), as agriculture accounts for 79 % of water withdrawals in Sub-Saharan Africa, even though the development of irrigation infrastructure is thus far very limited. As 10 % of the land area is cultivated, including the most fertile and productive lands, agriculture is also important for SDG 15 (protection of terrestrial ecosystems).

Agriculture plays an important role in programmes providing financial and technical assistance of both multi- and bilateral donor organizations. For example, German Official Development Assistance (ODA) to the agriculture sector in Sub-Saharan Africa amounted to 93.3 million EUR in 2015 alone, which represents 81 % of the assistance provided to production sectors (BMZ 2015).

A high dependence on precipitation, low availability of agricultural inputs and irrigation and difficult access to markets due to poor infrastructure are among the factors which explain why the agricultural sector in Sub-Saharan Africa is very sensitive to the impacts of climate change. Extreme events such as floods and droughts, in addition to slow-onset events such as gradual changes in temperature and rainfall regime pose significant risks to agricultural production systems; these events have a high likelihood of increasing in the future (IPCC 2014). Key impacts on crop productivity in the region which are likely to occur with a high degree of confidence include:

- Heat and drought stress on crops due to changes in precipitation and temperature patterns¹⁵;
- Pest and disease damage due to higher mobility and emergence of new vectors;
- Flood impacts on food systems and irrigation infrastructure; and
- More pronounced land degradation, erosion and desertification processes, resulting in lower soil fertility and impacting agricultural production systems (IPCC 2014).

Adaptation measures in the agricultural sector have great potential to reduce the risks of climate-related impacts on crop productivity, both in the near term (2030–2040) and in the long term (2080–2100) (IPCC 2014). However, adaptation strategies of the agricultural sector in Sub-Saharan Africa are typically a complex combination of *technological, agronomic, governance* and *socio-economic* approaches (Shiferaw et al. 2014). These approaches should primarily aim at guaranteeing a sustainable intensification of agricultural production, minimizing losses along the value chain while minimizing climate-induced risks.

Technological approaches include the production and application of improved agricultural inputs such as drought- and pest-resistant seeds, and the improved use of agrochemicals for nutrient management and pest control in order to reduce the risk of production losses due to drought or pests. Improvement of water management in irrigation (for example, through sprinkler and localized systems) is another technical option for making the agricultural production system less dependent on naturally occurring rainfall.

¹⁵ Despite strong regional variations, the overall effect on yields of major crops is very likely to be negative. Maize, wheat and sorghum in particular have shown sharp yield decreases under high temperatures (Serdezhny et al. 2014).

Improving water availability, efficiently distributing it onto the field through irrigation, and maintenance of proper soil moisture levels are important factors for mitigating drought risk and avoiding environmental problems such as waterlogging and salinization of soils, as well as overdraft of aquifers. Currently, only 6 % of the agricultural area in the region is irrigated. Since agriculture accounts for almost 80 % of water withdrawals in Sub-Saharan Africa, an expansion of irrigated areas will have to go hand in hand with more efficient water use in irrigation to avoid conflicts with other water users (see section 2.5. on water management).

Improved transport and food storage facilities can guarantee access to markets and food, even when production is lower (for example, during droughts or extreme events).

Agronomic approaches envisage an improved management of soil, water and nutrients – for example, through integrated crop-forest-livestock systems, water harvesting, soil cover management, crop rotation and conservation agriculture approaches. Soil nutrient management and carbon management are important for an effective application of fertilizers and for the maintenance of a healthy soil structure in order to reduce the risk of soil loss and land degradation, which can be aggravated by climate change.

These approaches can help improve availability of water for crops through improved soil moisture management, increase resilience to pests through crop diversification and help reduce soil degradation through improvement of soil fertility and organic matter. They are being increasingly employed by farmers in different agro-ecological contexts in the region (Sharka et al. 2013) and can also play a role in stabilizing soil carbon and contributing to climate change mitigation.

Pest management is an important issue in the adaptation of agricultural production systems to climate change in order to lower the risk posed by the emergence and increased mobility of pests and diseases. This includes proper application of agrochemicals, as well as other good agricultural practices which increase resilience to pests and diseases such as intercropping and crop rotation.

Governance approaches include strengthening political and institutional frameworks of the agricultural sector – for example, trade relations, tenure and access to nat-

ural resources and capacity building through extension services. Improvement of quality information to facilitate decision making by farmers (for example, agro-climatic information and technical options for adaptation), is an important pathway to climate change adaptation. Clear and secure rights to land also play a major role, as they enable farmers to make investments such as terraces or irrigation infrastructure.

Socio-economic approaches include improving the access of farmers to resources (for example, through credit), the diversification of income sources in order to reduce the dependency on agriculture and improved disaster preparedness. Lack of access to credit in particular is frequently cited as a major barrier to climate change adaptation by farmers in Sub-Saharan Africa. Credit enables farmers to invest in adaptation strategies and meet the transaction costs associated with adaptation processes (Sharka et al. 2013).

The relevance of different kinds of adaptation measures and approaches depends on the respective country and sectoral context. Additionally, the scale of adaptation may vary greatly from one case to another. For example, different strategies should be selected for smallholder farming sectors on the one hand and large-scale agroindustry farming on the other hand.

2.4.2. Significance of quality infrastructure services

Quality infrastructure services play an important role in addressing quality challenges along the agricultural and food value chains – for example, by:

- Ensuring the transparency and fairness of market transactions and correctly determining the quality and quantity of agricultural inputs and products;
- Increasing the safety and competitiveness of agricultural products in local and international markets through processes for conformity assessment with food safety, health and environmental regulations as well as international standards required for market access; and
- Supporting innovations through development and dissemination of standards on innovative technologies and practices (PTB 2014, World Bank 2017).

Quality infrastructure services become increasingly important for agricultural value chains in Sub-Saharan Africa in times of climate change. Considering the effects of climate change described above, important contributions of quality infrastructure can be summarized as follows.

- **Metrology:** Provides calibration, intercomparisons and reference material required by testing laboratories, secondary calibration laboratories and users of testing equipment in the sector. These services are fundamental to ensuring traceability and increasing the exactitude of tests and measurements in the sector. They become increasingly important in times of climate change in Sub-Saharan Africa, as they provide the basis for an efficient use of increasingly scarce resources as soil, nutrients and water. Additionally, they are needed for an effective quality control of agricultural inputs such as fertilizers, pesticides and products. An example is the reliable determination of moisture in grains, which is a key parameter to protect customer health in times of changing climatic conditions due to climate change.
- **Standardization:** Provides commonly agreed criteria for agricultural products, processes and systems. Standardization increases the efficiency of agricultural value chains and creates the basis for an effective quality management. To cope with the effects of climate change, increased efficiency of the agricultural sector is fundamental as reduced yields, for example due to higher temperatures, more common pest infestations and extreme weather events need to be compensated. Additionally, by considering the specific climatic conditions in Sub-Saharan Africa, standards can foster the adaptation of the agricultural sector.
- **Testing, Certification and Inspection:** These are required to ensure conformity of agricultural products, systems and personnel with quality criteria. The related services are increasingly important in times of climate change in Sub-Saharan Africa, as changing environmental conditions as well as their effects on the agricultural sector have to be monitored to create the basis for the required adaptations. Certifications and inspections confirm compliance with international standards and protect customers of the agricultural sector. Both are increasingly important in changing climatic conditions in Sub-Saharan Africa.

- **Accreditation:** Ensures the technical competence of laboratories, certification and inspection bodies. The assurance of reliable metrology and conformity assessment is increasingly important, as important decisions on adaptation measures and climate policies must be taken based on the information provided by these services. The international recognition of accreditation bodies in Sub-Saharan Africa is important for the agricultural sector to ensure the unified application of international standards and permit the international trade of agricultural products. The trade of agricultural products between countries in Sub-Saharan Africa may contribute to food security in times of climate change.

All sectors of quality infrastructure including metrology, accreditation and conformity assessment play a fundamental role in addressing different quality challenges in the agricultural sector along the associated value chains. Services should therefore be developed systematically and according to the specific needs of the sector.

2.4.3. Identification of sub-sectors relevant in Sub-Saharan Africa

The selection of sub-sectors along the value chain is based on an evaluation of their relevance for the agricultural sector in Sub-Saharan Africa (based on their relevance in times of climate change) and the relevance of quality infrastructure services throughout the value chain. Based on this analysis, the following sub-sectors were selected:

1. Pre-production (resilient seeds, fertilizers and pesticides);
2. Production (water, soil nutrient and carbon as well as pest management);
3. Post-harvest (climate-proof storage facilities).

Given the diverse agro-ecological zones and climatic and socio-economic conditions in the region, not all processes are equally important in each setting. Hence, the relevance and demand for quality infrastructure services (e.g. for livestock, food processing) may differ regionally.

Pre-production: Agricultural inputs (seeds, fertilizers and pesticides)

The supply of agricultural inputs is a challenge in the region and plays an important role in technical strategies

for adaptation to climate change. The importance of improved access to high-quality inputs is likely to increase in the future as farmers have to adapt their production systems to climate change, and for the sector to increase production levels to feed a growing population. Inputs can be instrumental in coping with (i) changed temperature and precipitation regimes through improved drought-resistant seed material, (ii) increased mobility of pests and diseases through effective agrochemicals which protect plants and (iii) varying degrees of land degradation through fertilizers (see subsection 2.4.1.). Quality infrastructure can help assure consumers of the quality of agricultural inputs (seeds, fertilizers and pesticides). Relevant services include the development of certification and labelling schemes for agricultural inputs, calibration of equipment for exact determination of weight, volume and active ingredients of agrochemicals, as well as capacities of test laboratories to verify the quality of products.

Production (Management of soil nutrients and carbon, water, pests and diseases)

The proper management of water and soil resources in agriculture is critical for farmers in Sub-Saharan Africa to adapt their production systems to climate change. Soil and water management plays a key role in the implementation of technical and agronomic approaches to climate change adaptation as described above. Quality infrastructure services can help optimize processes in the agricultural production stage, for example through the development of standards, guidance documents and certification systems for climate smart agricultural practices adapted to local and regional contexts. Furthermore, quality infrastructure services can be relevant in improving farmers' information, for example, through the determination of soil quality and optimizing water application to crops. Quality infrastructure services can help improve the understanding of the carbon balances in agricultural soils as well.

Post-harvest (climate-proof storage facilities)

In Sub-Saharan Africa, post-harvest losses during storage and handling amount to 8 % for cereals, oilseeds and pulses and to 18 % for roots and tubers (FAO 2011). These amounts are comparable to the losses which occur during growing and harvest. Deficient facilities and protocols for storing and drying agricultural produce are a major cause of these losses. Inadequate storage conditions cause economic losses and health risks as mycotoxins can develop in stored grains if moisture is not controlled properly. Improved climate-proof food storage capacity is an im-

portant element of adaptation of the agricultural sector to climate change, as it can attenuate losses during growing and harvesting due to extreme weather events such as floods and droughts, which may be triggered by changed temperature and precipitation regimes in times of climate change. Quality infrastructure has an important role to play in improving the construction, management and operation of storage (moisture, temperature and humidity).

2.4.4. Demand for quality infrastructure services in Sub-Saharan Africa for the identified sub-sectors

In this subsection, the demand for quality infrastructure services is explained along the components of the agricultural value chains of the selected sub-sectors.

Pre-production: Agricultural inputs (seeds, fertilizers and pesticides)

Ensuring the quality and quantity of agricultural inputs available on local markets is the main challenge of pre-production. Quality criteria for drought, temperature and pest-resistant seed material are germination, purity, moisture content and traceability to the producer of the seeds. For fertilizers, macronutrients (nitrogen, phosphorus, potassium) and micronutrients contained are relevant. For pesticides, quality criteria for chemicals which kill, control or repel pests are the "active ingredients"

For all inputs, the correct and transparent determination of weight and volume is important along the distribution chain from producer to consumer.

As most of the agricultural inputs are imported, prices are prohibitively high for a large segment of small and subsistence farmers, which limits their capacities to adapt to climate change, as they often rely on sub-standard products which are offered at lower prices. Efforts to improve quality infrastructure need to take into account the strengthening of processes which enable access of these farmers to affordable quality agricultural inputs, for example by creating standards for specialized agricultural inputs adapted to specific climatic conditions which create the basis for national production.

Metrology

Metrological services are of great importance to ensure

quality control of agricultural inputs. In countries where the necessary metrological services are not offered, farmers, authorities and service providers must rely on calibration services in other countries. This leads to increased costs and longer turnaround times. Therefore, in many countries in Sub-Saharan Africa, farmers, supporting organizations, laboratories and the authorities do not calibrate all relevant equipment. This leads to a lack of traceability and exactitude in the sector. Both are increasingly important in times of climate change, as they are the basis for efficient agricultural systems and for the monitoring of the quality of agricultural products under changing environmental conditions. Metrology in chemistry is also relevant in this context because it provides traceability for the determination of the active ingredients in fertilizers and pesticides, for example.

In terms of legal metrology, verification of balances and scales is necessary to ensure the correct weight of products such as pesticides at the point of sale. Functioning legal metrology is important to ensure market transparency and protect customers. The correct weighing of agricultural inputs creates the basis for an efficient application, which is increasingly important in times of climate change.

Standardization

Standards and guidance documents play an important role in the process of providing the quality assurance of agricultural inputs. With regard to seed material and testing, OECD seed schemes define standards which form the basis for participation in global OECD seed certification (OECD 2017). The International Seed Testing Association (ISTA), a network of seed laboratories, has developed standards for sampling and testing seeds.

At the sub-regional level, the East African Community has developed draft standards for the certification of seeds such as sorghum and groundnut, based on ISTA and OECD standards (EAC 2014a, EAC 2014b).

For fertilizers, ISO Technical Working Group 134 has published a series of standards for the determination of ingredients, sampling procedures and labelling of fertilizer products (see Table 8).

National standards bodies are responsible for adopting national standards based on the relevant international and regional standards, and for adapting them to local

conditions if necessary. For example, standards and test protocols for seed testing are increasingly relevant, as tests under varying climatic conditions and regarding the resistance of the seed material to emerging pests are required. At the regional or sub-regional levels, standards for the certification of drought-, heat- and pest-resistant seed varieties could be adopted based on the existing standards, improving the ability of the agricultural systems in Sub-Saharan Africa to cope with the expected changes of the climatic conditions. A regional harmonization of quality standards for seeds and other inputs can favour the integration of markets in the sector and improve access to quality goods, also in countries which do not have a strong National Standards Body. In any case, the participation of national and regional standards bodies in the development of international standards and in related discussions is paramount to making sure that the perspective of Sub-Saharan Africa is taken into consideration in the development of new standards for the agricultural sector.

To encourage application of the standards, a national standards body can provide guidance or best practice documents for the production and testing of agricultural inputs.

Testing, Certification, Inspection

Relevant testing capacities to assess the quality of agricultural inputs include the determination of quality parameters for seeds (moisture, germination and purity), fertilizers (macro- and micronutrients) and the active ingredients of pesticides, according to international standards. Seed testing procedures include both laboratory and field testing. Necessary testing capacities therefore also include soil parameters such as nutrient content, humidity and acidity. In many countries in Sub-Saharan Africa, the relevant services are offered by testing laboratories, but often the tests are not realized according to international testing procedures or have not applied quality management systems. As important decisions by farmers, supporting organizations and authorities are made based on the results of agricultural testing laboratories, it is important to improve the quality management of laboratories and confirm their technical competence with an internationally recognized accreditation (see the section on “Accreditation”).

The development and implementation of certification and labelling schemes for agricultural inputs is an important task to ensure market transparency for these products.

This includes the design of the scheme based on international standards as well as setting up and strengthening certification bodies. In this context, awareness-raising campaigns for farmers and farmer organizations about the benefits of certified products are also important.

Inspection services play a major role in the quality assurance of the available inputs. In times of climate change, these services are increasingly important for creating the basis for efficient and effective use. For example, in many Sub-Saharan African countries, the actual content of active ingredients varies widely from the contents indicated on the packages of fertilizers. This leads to an incorrect application: too much or too little fertilizer is being applied. Systematic product inspections could contribute to improving this situation.

The lack of efficient control procedures of imported agricultural seeds and fertilizers is an important obstacle for local markets in Africa (World Bank 2017). Registration schemes for fertilizers, pesticides and seeds based on global standards and backed by competent laboratories can serve to streamline inspection procedures, lower costs for the producers and, consequently, the prices for local farmers.

Accreditation

Accreditation services relevant for agricultural inputs include the accreditation of testing and calibration laboratories in accordance with ISO 17025, the accreditation of certification bodies in accordance with ISO 17065 and the accreditation of inspection bodies in accordance with ISO 17020.

In some countries in Sub-Saharan Africa, accreditation bodies do not exist at present. This means that accreditation services relevant for the agricultural sector must be offered by foreign bodies, leading to increased costs and limited accessibility. Both costs and accessibility may be improved by establishing cooperation agreements with existing internationally recognized accreditation bodies in the regional economic communities.

Regulations and transversal aspects

In addition to the regulations regarding the registration, certification and labelling of inputs, countries need to develop regulations on pesticide handling and use to ensure protection of food consumers, agricultural workers and the environment. This will be important in the future as

agriculture needs to adapt to emerging pests and diseases. These regulations need to take quality infrastructure services into account, for example by requiring that pesticide residues in food be determined by duly accredited laboratories.

Production: Management of soil nutrients and carbon, water, pests and diseases

Quality challenges in agricultural water management are related to the proper registration of water withdrawals for agricultural purposes from surface and groundwater sources as well as to the equitable distribution of water within an irrigation system. Furthermore, reliable measurements of soil humidity are needed to enable an effective dosage of irrigation water and the correct application of good management for irrigation and other forms of maintaining soil humidity such as mulching and cover crop management. Finally, depending on the context, water quality needs to be monitored to avoid damage to crops, the environment and human health.

Quality challenges regarding soil nutrient and carbon management in agriculture are related to the correct assessment of nutrient and carbon contents in the soil. The maintenance of proper nutrient and carbon levels requires the application of management practices adapted to local contexts including fertilizer application, cover crop management and crop rotation. Furthermore, precise soil maps need to be developed to enable sound decision-making by farmers on the application of fertilizer and other nutrient management approaches. This requires precise analysis of soil samples to provide ground truth of the maps. The assessment of soil carbon is also relevant for climate change mitigation and for the assessment of carbon emissions and reductions in the framework of the United Nations Framework Convention on Climate Change (UNFCCC) reporting process.

Quality challenges in pest management include the correct application of good practices such as crop diversification and rotation, correct handling, application of pesticides in the field as well as the determination of pesticide residues in the harvested products. Also, the protection of field workers from exposure to toxic pesticides is important, as is the proper disposal of residues and containers.

Metrology

Metrological services relevant for agricultural water management include, for instance, the calibration of equip-

ment for water meters used in irrigation as well as for water quality parameters. For precise measurements of groundwater levels, the calibration of piezometers for hydrostatic pressure is important. Furthermore, calibration services for soil humidity testing equipment are needed. Additionally, type approval of common equipment (e.g. flow meters, piezometers) must ensure the appropriateness of the equipment used. At farm level, the availability of properly calibrated instruments can help farmers improve the efficiency of water application according to crop water requirements. At irrigation system and river basin level, it is a prerequisite for transparent water allocation by irrigation managers and regulatory agencies. A lack of calibration services can lead to inefficient use of water and to inappropriate distribution.

In terms of soil nutrient and carbon management, calibration services for testing equipment for the determination of physical and chemical soil parameters are needed to help farmers make informed decisions about crops and ensure an application of correct doses of inputs. Inadequate knowledge of soil characteristics can lead to stress on the plants and production losses.

For pest management, calibration services and type approvals of volumetric equipment, flow meters and pumps used for pesticide application are required. In terms of chemical metrology, the calibration of equipment to determine pesticide residues in agricultural produce as well as the production of reference material and the organization of round robin tests are needed. If such services are not available, the proper application of agrochemicals cannot be guaranteed, limiting their effectiveness. Also, overdoses have negative consequences for the health of farmers and agricultural workers, consumers and ecosystems.

Standardization

In terms of farm equipment for irrigation, fertilizer and pesticide application, there is a range of international standards which have to be adopted or adapted to national contexts (see Table 8). At regional and national levels, it is important to develop standards for the functioning of locally used equipment such as hand or treadle pumps, or manual equipment for seed planting, which are not covered by international standards. Such regional or national standards become increasingly important in times of climate change, as they are able to address the specific environmental conditions and practices in Sub-Saharan Africa.

In peri-urban areas, the safe use of treated wastewater in irrigation is an issue which will require increasing attention in the future, as water scarcity will rise as a consequence of climate change. National or regional standards or guidance documents on safe wastewater can be developed based on international standards and ISO guidance documents and applied in agriculture. In addition, the WHO provides guidelines on the use of wastewater in agriculture and irrigation projects (ISO 16075-1:2015 WHO 2006)

The development and revision of guidance documents on good practices for water, nutrient, soil carbon and pest management in the context of climate change (climate-smart agriculture) is an important task. These guidance documents should be practical aides for farmers and extension workers and be based on international standards and accepted good practices such as conservation agriculture, agroforestry practices, soil cover management, crop rotation and intercropping. They need to be carefully tailored to local cultural and agroecological contexts in Sub-Saharan Africa to ensure relevance and adoptability.

Regional standardization organizations as well as national standards bodies can facilitate processes with the agricultural sector on the development, publication and dissemination of standards for farming equipment and guidance documents on good agricultural practices for climate change adaptation and mitigation.

Testing, Certification and Inspection

Field-level testing of soil and water quality parameters is important for the optimization of water and soil management practices, for example, to determine the right dose of agrochemicals or irrigation scheduling. As access to testing laboratories is limited in rural areas, the development and distribution of field test kits is an option for farmers. Training farmers to use test kits and sampling techniques correctly is essential.

Testing capacity of soil quality and structure in laboratories is important for the preparation of soil maps and the ground truthing of remote sensing information derived from satellite images, which can provide a preliminary assessment to farmers about the quality of the soil and inform their decisions on adaptation options. It is also an important input to the monitoring on soil carbon assessments in the context of projects for mitigation of climate

change in the Land Use, Land Use Change and Forestry (LULUCF) category. This can be achieved through building and strengthening soil laboratory capacities in the application of portable solutions such as field portable spectroscopy and innovative technologies such as the flash combustion method for determination of total and organic carbon (see Section 3.1 on Kenya, ICRAF n.d.).

In irrigated agriculture, the determination of water volume at the source and within irrigation systems as well as hydrostatic pressure in groundwater is important for monitoring compliance with water abstraction permits, limit groundwater overdraft, ensure effective and transparent distribution of water to different users and to ensure irrigation planning at field level. Irrigation departments, water user groups and farmers need technical competence to carry out these tasks.

Certification schemes of good agricultural practices such as Global G.A.P and Organic Farming can be an important instrument to promote climate smart agricultural practices, improve the market access of farmers and increase the value of their produce. However, smallholders have difficulties accessing international certification schemes due to the elevated cost, high technical and reporting requirements of the schemes and the limited access to markets which reduces the incentive for the farmers. As an alternative, either regional capacities for assessing conformity with international standards can be developed (e.g. accredited certification bodies) or regional or national certification schemes can be created based on local standards for good practices. An example of a certification scheme for climate smart agricultural practices in developing countries is the Sustainable Agriculture Standard developed by the Sustainable Agriculture Network and the Rainforest Alliance (RAS 2017).

Inspection capacities for water and environmental authorities need to be built with a focus on controlling agricultural water abstraction from surface and groundwater, particularly in those areas where investments in irrigation are foreseen to adapt agricultural production to climate change. Inspection services are also needed to monitor compliance with regulations on the safety of agricultural workers, in particular regarding agrochemicals.

Accreditation

Access to accredited laboratories is important, for instance, for food safety inspections to determine microbial contamination, which may increase in changing climatic conditions.

Thus, internationally recognized accreditation services are important as well, as they allow for regional and international cooperation in the realization of calibration, testing, certification and inspection services needed for agricultural production. This cooperation is especially important in Sub-Saharan Africa, as not all of the services relevant for the agricultural sector are provided nationally.

For this reason, it is important to ensure that the service providers have access to internationally recognized accreditation services relevant for agricultural production in all countries of Sub-Saharan Africa, either via accreditation bodies in their own countries or via cooperation with other bodies in the region (see further explanations in Subsection 2.4.3 “Pre-Production: Agricultural inputs”).

Regulations and transversal aspects

Currently, water abstractions in Sub-Saharan Africa are mainly used for agriculture-related services. This situation is likely to increase as irrigation infrastructure is built or improved to make agriculture resilient to changing rainfall patterns. In this context, regulations on agricultural water use are important for governing water management, particularly where competition with other water users exists.

Likewise, the use of (un)treated wastewater is of concern in peri-urban areas of the region and needs to be regulated to minimize risks for human health and the environment (see section 2.6. on human health). These regulations should make reference to quality infrastructure elements, such as standards or analysis by accredited laboratories. A strengthening of agricultural extension systems is required to provide access to improved quality infrastructure services facilitating, for example, the dissemination of guidance documents and standards on climate-smart management practices, soil maps or testing equipment to farmers.

Finally, the development of easily accessible climate forecasting and weather information services for farmers backed by quality infrastructure can be important for guiding a farmer’s management decisions. This is dealt with in detail in the meteorology section (see 2.3).

Post-harvest: Climate-proof storage facilities

Quality challenges for post-harvest storage facilities include maintaining correct storage conditions (temperature, humidity, cleanliness) and maintaining drying facilities to guarantee adequate moisture contents of the stored goods.

Metrology

Metrological services include calibration of testing equipment to determine weight, temperature and humidity, as well as moisture content in agricultural commodities.

Inaccurate calibration of the equipment for the determination of temperature, moisture and humidity can lead to the loss of stored produce and health risks to consumers due to the propagation of mycotoxins. As temperature, humidity and moisture patterns will change as a result of climate change in Sub-Saharan Africa, a reliable monitoring of these parameters is increasingly important. Furthermore, lacking calibration of weighing scales and balances leads to incorrect determination of the weight of agricultural products, resulting in unreliable information for the monitoring of agricultural production and in incorrect payments.

Lacking traceability and exactitude of measurements can also lead to problems during later stages of the value chains. For example, they can result in inadequate conditions during transport, negatively impacting the quality and safety of the products. In turn, this can reduce the competitiveness in national and international markets. As mentioned before, the international and regional trade of agricultural products is increasingly important for adapting agricultural production to the effects of climate change in Sub-Saharan Africa.

Standardization

International standards relevant for the storage of grains and pulses are included in the ISO Standards catalogue ISO/TC 34/SC 4.¹⁶ For other post-harvest processes, international standards also define adequate systems and quality criteria. To promote appropriate post-harvest methods in times of climate change in Sub-Saharan Africa, it is important that the national standards bodies adopt international standards. Considering the changing conditions due to climate change, it should be evaluat-

ed whether an adaptation to the specific conditions in Sub-Saharan Africa is necessary or not.

In order to facilitate the application of standards by farmers, operators of storage facilities and further organizations involved in post-harvest processes at the local level, national standardization bodies may develop best practice documents and practical guidance documents based on international standards. In the context of Sub-Saharan Africa, regional and sub-regional standards organizations such as the ECA may play an important role in the development and dissemination of such guidance documents.

Testing, Certification, Inspection

Testing services required to maintain adequate storage conditions include the monitoring of temperature, humidity and weight. Determination of the moisture content of the stored commodities is important for the performance assessment of the drying system. Testing for mycotoxins and residues of fungicides or other conditioning agents should be undertaken in order to assess the food safety of the stored goods. Especially, reliable testing services for mycotoxins and relevant residues are lacking in many countries in Sub-Saharan Africa at present. In the short term, the demand for testing services in the mentioned areas may be met by other laboratories in the region. However, in the longer term, it will be necessary to also build up these testing capacities nationally, considering their increasing importance in changing climatic conditions.

Inspections of post-harvest storage facilities should be carried out regularly by competent authorities to ensure that the facilities comply with sanitary regulations. Inspections of stored produce are important for ensuring that the goods comply with food safety regulations. At present, the inspection bodies in Sub-Saharan Africa are often lacking sufficient capacities and training, resulting in an insufficient control of the post-harvest processes. This can lead to severe losses of agricultural produce and health risks for the consumer, especially in times of climate change.

Accreditation

Accreditation services relevant for post-harvest storage facilities include accreditation of testing and calibration laboratories in accordance with ISO 17025 (ISO 2005) and of inspection bodies in accordance with ISO 17020 (ISO 2012a). Access to accredited laboratories is important, for

¹⁶ In particular ISO 6322-1:1996 (Storage of cereals and pulses), ISO 11520-1:1997 (Agricultural grain driers – Determination of drying performance), and ISO 712:2009 (Cereals and cereal products – Determination of moisture content – Reference method).

instance, for food safety inspections with regard to mycotoxin residues. Likewise, the credibility of inspection bodies can be improved through accreditation according to international standards. Furthermore, an internationally recognized accreditation of calibration, testing, certification and inspection services provides the basis for the regional and international trade of agricultural products (see Section 2.4.4., “Production: Management of soil nutrients and carbon, water, pests and diseases”).

Regulations and transversal aspects

Regulations must define the requirements for the control of aspects which can impact the health of the consumers of agricultural products. This control is increasingly important in times of changing climatic conditions in Sub-Saharan Africa.

To guide the construction and operation of storage facilities, regulations on food storage need to be revised. Reference should be made to quality infrastructure criteria, for example by including testing of stored goods by accredited laboratories. Furthermore, regulations could limit or prohibit the construction of storage facilities in flood-prone areas to increase resilience to natural disasters associated with climate change.

Quality infrastructure services/Value chain	Quality challenges	
Drought-, temperature- and pest-resilient seeds	<ul style="list-style-type: none"> Quality of inputs Seeds: weight, germination, purity, moisture content, traceability 	
Fertilizers	<ul style="list-style-type: none"> Quality of inputs Fertilizers: weight, composition: macro- (N,P,K) and micronutrients 	
Pesticides	<ul style="list-style-type: none"> Quality of inputs Pesticides: weight, volume and active ingredients 	

Table 5: Quality issues and necessary services of quality infrastructure along the pre-production value chain (for the application of standards, please refer to the selected standards in Table 8)

Quality infrastructure services/Value chain	Quality challenges	
Water management for agricultural production	<ul style="list-style-type: none"> Monitoring of groundwater/ well capacities Monitoring of water abstraction Correct water application in the field Control of ambient water quality 	
Soil nutrient and carbon management	<ul style="list-style-type: none"> Assessment of soil nutrient contents Correct application of fertilizers Adequate soil maps 	
Pest management	<ul style="list-style-type: none"> Good agricultural practices Correct application of pesticides (dosage, health protection) 	

Table 6: Quality issues and necessary services of quality infrastructure along the production value chain

Quality infrastructure services/Value chain	Quality challenges	Metrology	
Climate-proof storage facilities	<ul style="list-style-type: none"> Correct storage conditions 	<ul style="list-style-type: none"> Equipment calibration 	

Table 7: Quality issues and necessary services of quality infrastructure along the post-harvest value chain

	Metrology	Standardization	Testing	Certification	Inspection	Accreditation	Regulation/Transversal aspects
	<ul style="list-style-type: none"> Equipment calibration, chemical metrology 	<ul style="list-style-type: none"> Harmonization of standards for improved varieties Consideration of guidance documents/best practice Informing users of existing standards Participation in mirroring of ISO Groups 	<ul style="list-style-type: none"> Testing of inputs (seeds, fertilizers, pesticides according to quality parameters) Application of testing and sampling procedures 	<ul style="list-style-type: none"> Implementation of certification and labelling schemes for agricultural inputs and products 	<ul style="list-style-type: none"> Regular inspection of inputs by competent authorities 	<ul style="list-style-type: none"> Accreditation of calibration laboratories, certification and inspection bodies 	<ul style="list-style-type: none"> Registration, certification and labelling schemes for agricultural inputs (seeds, fertilizers, pesticides)

	Metrology	Standardization	Testing	Certification	Inspection	Accreditation	Regulation/Transversal aspects
	<ul style="list-style-type: none"> Equipment calibration Chemical metrology Verification of macro- and micro flow meters 	<ul style="list-style-type: none"> Consideration of guidance/best practices Harmonization of national/regional standards 	<ul style="list-style-type: none"> Testing of water flow, groundwater pressure and levels Testing of in situ soil humidity Testing (field test kits) of irrigation water quality 	<ul style="list-style-type: none"> Certification of field test kits for water quality 	<ul style="list-style-type: none"> Inspection of irrigation water abstraction 	<ul style="list-style-type: none"> Accreditation of testing laboratories, calibration laboratories, certification and inspection bodies 	<ul style="list-style-type: none"> Regulations on agricultural water abstractions Development of functioning climate forecasting and weather information communication Development of information and early warning systems on prevalence of agricultural pests and diseases Strengthening of agricultural extension services
	<ul style="list-style-type: none"> Equipment calibration for soil quality analysis 		<ul style="list-style-type: none"> Testing of soil properties 	<ul style="list-style-type: none"> Certification of good agricultural practices 			
	<ul style="list-style-type: none"> Equipment calibration for determination of active ingredients 		<ul style="list-style-type: none"> Testing of pesticide residues in agricultural products 	<ul style="list-style-type: none"> Certification of good agricultural practices 	<ul style="list-style-type: none"> Food safety inspections Inspection of safety of agricultural workers 		

	Standardization	Testing	Certification	Inspection	Accreditation	Regulation/Transversal aspects
	<ul style="list-style-type: none"> Consideration of guidance/best practices Adoption of national/regional standards 	<ul style="list-style-type: none"> Monitoring of storage conditions: Temperature, humidity Testing of moisture, pesticide, residues and mycotoxins in agricultural products 	<ul style="list-style-type: none"> Certification of storage facilities 	<ul style="list-style-type: none"> Inspections of storage facilities Food safety inspections of stored goods 	<ul style="list-style-type: none"> Accreditation of laboratories (testing/calibration) and inspection bodies 	<ul style="list-style-type: none"> Inclusion of quality criteria in regulations on food storage facilities Regulations on construction outside of flood-prone areas

Production chain	Element	Standards, technical groups etc.
Pre-production	Seeds	OECD Seed standards ECA Seed standards
	Fertilizers	ISO Technical Group 134 Fertilizers and soil conditioners
	Pesticides	ISO Catalogue 65.100.01 Pesticides and other agrochemicals in general
Production	Agricultural water management	ISO 21413:2005 Manual methods for the measurement of a groundwater level in a well ISO/TR 23211:2009 Hydrometry – Measuring the water level in a well using automated pressure transducer methods ISO 16399:2014 Meters for irrigation water ISO/TC 23/SC 18 Irrigation and drainage equipment and systems ISO 16586:2003 Soil quality – Determination of soil water content ISO/TC 147 Water quality ISO 16075-1:2015 Guidelines for treated wastewater use for irrigation projects
	Soil nutrient and carbon management	ISO 65.060.25 Equipment for storage, preparation and distribution of fertilizers ISO/TC 190 Soil quality
	Pest management	ISO/TC 23/SC 6 Equipment for crop protection
Post-harvest	Climate-proof storage facilities	ISO 6322-1:1996 Storage of cereals and pulses ISO/TC 34/SC 4 Standards catalogue Cereals and pulses ISO 11520-1:1997 Agricultural grain driers – Determination of drying performance

Table 8: Selected standards related to sub-sectors in the agricultural production chain



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2.5. Water

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2.5.1. Current trends in the sector in times of climate change (global and regional)

SDG 6 addresses issues related to drinking water, sanitation and hygiene, but also protection and the sustainable use of water resources in a broader sense. Its achievement is at the very core of sustainable development and critical to the survival of humans and ecosystems (UN-SDGs 2017).

Prior to the SDGs, the Joint Monitoring Programme for Water Supply and Sanitation, as part of the Millennium Development Goals (MDG) system, monitored achievements within this sector. Some of the Joint Monitoring Programme outcomes for Sub-Saharan Africa as by 2015 are the following:

- Rivers, lakes, ponds and irrigation canals are still used in Sub-Saharan Africa as a main source of drinking water. Only less than 50 % of the population in many Sub-Saharan Africa countries uses improved drinking water sources.
- 13 % of the population in Sub-Saharan Africa used unimproved drinking water sources in urban areas and 44 % in rural areas.
- In many countries located in Sub-Saharan Africa, less than half the population had access to improved sanitation.
- 60 % of population in Sub-Saharan Africa had unimproved sanitation facilities in urban areas and 77 % in rural areas (UNICEF & WHO 2015).

There is a large disparity in access to clean water between Sub-Saharan Africa and other regions of the world. Based on the Food and Agriculture Organization's (FAO) global water information system AQUASTAT 2010, water withdrawal by sectors in Sub-Saharan Africa amounts to 16 % for municipal use, 5 % for industrial use and 79 % for agricultural use (FAO 2016).

The urban population has more access to clean water than the rural population. The prevalence of water-related

ed diseases in regions which lack access to safe drinking water and improved sanitation facilities is a critical issue in Sub-Saharan Africa. Gender inequalities related to water are also a great concern in some countries due to women's responsibility for collecting water (Hannemann 2015).

Insufficient treatment of water and wastewater, particularly combined with rapid population growth and urbanization, is aggravating the lack of clean (drinking) water in Sub-Saharan Africa. Centralized sewage plants face great challenges due to little investment in the sewage infrastructure. As a consequence, sewage is often disposed in water bodies without treatment, causing heavy pollution. Water pollution has different impacts on societies and the natural environment such as the reduction of available fresh water and negative effects on human health and ecosystems.

Due to poor urban planning and rising population, illegal settlements and slums are emerging and growing at alarming rates. Domestic wastewater is therefore a major source of water pollution. In these settlements, most residents have no access to sanitation or sanitation systems are limited due to a lack of sewerage collection systems and wastewater treatment plants.

Likewise, industries in Africa (sugar, textiles, paper, etc.) often use treatment systems with inadequate processes such as stabilization ponds for industrial water treatment. They sometimes do not have enough capacities, leading to very high pollutant concentrations in the effluent of pond systems (Wang et al. 2013).

The links between climate change and water-related risks are numerous and very context-specific (IPCC 2014). Altogether, climate change represents a huge challenge for different water-related sectors in Sub-Saharan Africa (drinking water, water for irrigation, industrial water, etc.). Climate change in Sub-Saharan Africa will affect river-runoff, posing a risk of shallow groundwater contamination due to intense rainfall. Groundwater recharge rates have been projected to decline and increase in different regions of Sub-Saharan Africa. This is particularly important because of the reliance of some rural populations in Sub-Saharan Africa on groundwater as a source of safe drinking water. For example, due to several changes like population and economic growth and increasing evaporative losses in Sub-Saharan Africa, factors like irrigation

and hydropower production will increase water demand. This poses substantial threats to water security. Projected increases of droughts and an expected expansion of irrigated land particularly in semi-arid regions combined with population growth and growing demand will lead to increases in groundwater extraction. Drought conditions can affect the availability and quality of water and can be linked to different water-related illnesses.

Water scarcity is not the only climate change-related challenge, since many countries in Sub-Saharan Africa are, and will remain, vulnerable to flooding which affects coastal areas as well as inland regions: Due to sea-level rise, coastal populations in Mozambique and Nigeria are projected to be most affected when considering the absolute number of people flooded annually. Mozambique and Guinea-Bissau are projected to experience the highest annual damage costs in terms of economic impacts, due to coastal floods, forced migration, salinity intrusion and loss of dry land associated with sea level rise. Following extreme weather events such as floods, outbreaks of transmittable diseases (either food-, water- and/or vector-borne ones) can occur. Heavy rainfall events and both coastal and inland floods, combined with elevated temperatures, can lead to outbreaks of cholera, which are associated with contaminated water and poor sanitation.

Due to sea level rise, shifts in climatic conditions or extreme weather events, Sub-Saharan Africa is expected to be particularly affected by migration. Especially when migrants come to reside in precarious conditions, the new place of residence can place people at risk. Inadequate sanitation and water drainage infrastructure triggers dependence of residents on water supplies which can easily become contaminated (Serdeczny et al. 2016).

Adaptation strategies for the water sector recommended by the International Panel on Climate Change (IPCC) include strengthening institutional capacities of integrated water and wastewater planning, improving access to safe water and improved sanitation and strengthening institutional capacities for water demand management. In addition, increasing water use efficiency will also be an option for adaptation to more water scarce environments in Sub-Saharan Africa. Vulnerability mapping and early warning systems have the potential to influence and minimize climate change-related impacts and risk (IPCC 2014).

2.5.2. Significance of quality infrastructure services

As mentioned above, Sub-Saharan Africa especially lacks access to clean water compared to other regions in the world. Insufficient treatment of water and wastewater aggravates the water insecurity situation in Sub-Saharan Africa. Furthermore, climate change represents a huge challenge for different water-related sectors in Sub-Saharan Africa. Functioning quality infrastructure services are therefore very important for increasing sustainability in the water sector in times of climate change. In particular, they:

- Contribute to making drinking water, sanitation and wastewater treatment quality assurance systems more efficient, more reliable and sustainable so that consumers have access to drinking water (PTB 2013a);
- Improve the efficient use of scarce water resources in industry and agriculture, and increase the security of supply through exact and trustworthy consumption measurements (PTB, 2013a).

Therefore, strengthening national quality infrastructure is crucial in this context. This can be achieved through different specific quality infrastructure-related activities in the water sector:

- Promotion of new proposals for standards and policies or regulations where better criteria are set for quality in the water sector (PTB 2017), adapting international standards to regional conditions if necessary;
- Strengthened measurement capabilities for water quality and quantity, including flow and participation in intercomparison measurements;
- Reliable control of water pollution and water use by laboratories and water utilities through the use of quality infrastructure services, including periodic calibration of equipment, proficiency tests and accreditation;
- Support of accreditation bodies in the fulfilment of essential requirements to achieve international recognition for the accreditation of laboratories and inspection bodies (PTB 2013a, PTB 2013b).

Water-related quality infrastructure services such as reliable measurements of drinking water consumption, analysis of drinking water quality, control of water pollution at point of discharge and control of water treatment processes and others listed in tables 10, 11 and 12 below have great potential to support adaptation prospects such as recommended by IPCC. Figure 3 shows opportunities for quality infrastructure development with a potential to approach water-related climate change impacts and related risks in Sub-Saharan Africa.

2.5.3. Identification of sub-sectors relevant in Sub-Saharan Africa

The selection of water-related sub-sectors for the study is based on their present and future relevance for Sub-Saharan Africa in terms of climate change adaptation, the relevance of quality infrastructure services throughout the process chain and the development potential of the sub-sector. Based on this analysis, the following sub-se-

tors were selected: 1. Drinking water supply, 2. Wastewater and sanitation, 3. Industrial water management. Agricultural water management, which is also highly relevant in terms of climate change adaptation in the region, is discussed in section 2.4 on agriculture.

Already today, Sub-Saharan Africa water sectors face several challenges which are forecasted to be aggravated by socio-economic and demographic pressures:

Drinking water supply: Projected increases of droughts and higher exposure to floods due to socio-economic phenomena, such as overpopulation, are a given reality in Sub-Saharan Africa. They contribute to a higher demand of reliable and trustworthy water quality and flow measurements in order to ensure improved water supply services. Given these challenges, target 1 of SDG 6 aims at achieving universal and equitable access to safe and affordable drinking water for all by 2030.

Climate change impacts and related risk

Adaptation measures supported by quality infrastructure services

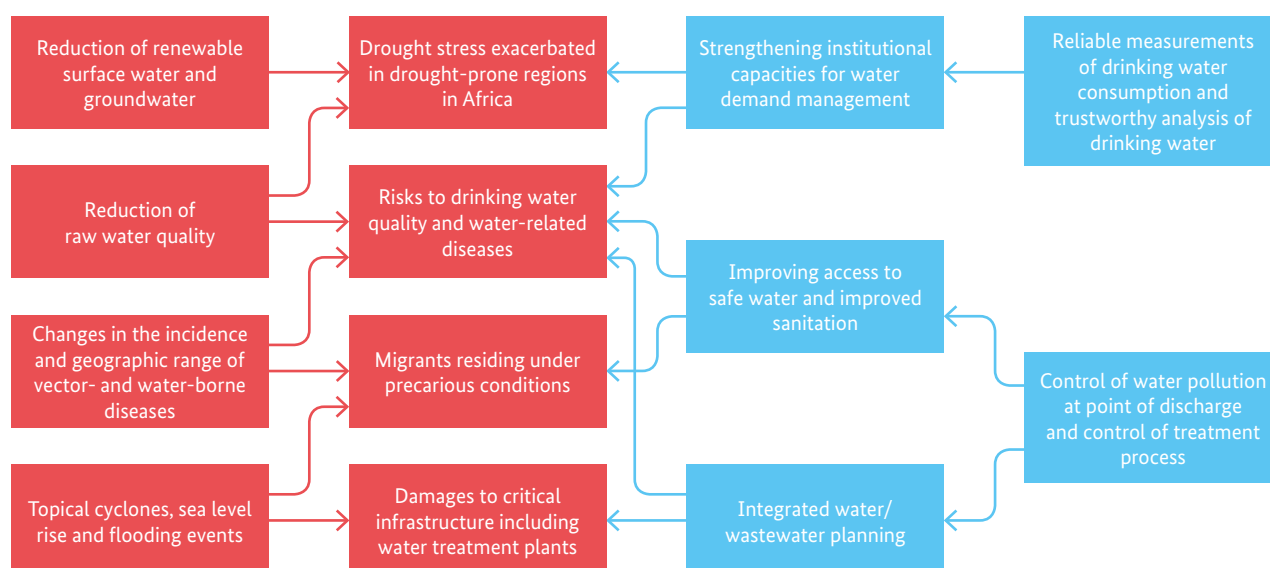


Figure 3: Climate change risks and adaptation measures supported by quality infrastructure services (our elaboration)

Wastewater and sanitation: Given the above-mentioned challenges, up-to-date water quality and flow measurements are required in order to identify high-risk water sources and determine effective water treatment methods. Thus, target 2 of SDG 6 aims at achieving access to adequate and equitable sanitation and hygiene for all by 2030.

Industrial water management: Insufficient treatment of water and wastewater as well as inefficient water use in the Sub-Saharan Africa context makes improved end of pipe water pollution control necessary. This also includes locally adapted standards for water quality after treatment. Against this background, target 3 of SDG 6 is to improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing water recycling and safe water reuse globally (Peletz et al. 2016, Wang et al. 2013, FAO 2016).

2.5.4. Demand of quality infrastructure services in Sub-Saharan Africa for the identified sub-sectors

The following section presents quality challenges in the selected sub-sectors and analyses the demand for quality infrastructure services to address these challenges. The tables at the end of this chapter provide an overview of the challenges and quality infrastructure demands for each sub-sector. Based on this analysis, the text provides a summary of the quality infrastructure demands in the sub-sectors along the lines of the main quality infrastructure pillars.

Metrology

The sub-sectors selected in this study (drinking water supply, wastewater and sanitation, industrial water management) require metrological services in terms of water quality and water quantity (flow measurement). Furthermore, measurement of hydrostatic pressure for the monitoring of wells is needed.

In terms of *water quality*, all sub-sectors require calibration services for basic physical, chemical and microbiological parameters such as temperature, pH, conductivity and turbidity. In order to ensure reliable water quality testing,

the equipment needs to be calibrated correctly and periodically. The capabilities of the national metrology institutes are not equally well developed in all countries of Sub-Saharan Africa. Moreover, secondary calibration laboratories in many countries also do not offer all services required. It is therefore not always easy for testing laboratories and other testing providers to calibrate all of their equipment. Periodic calibration can be expensive and time consuming, especially if equipment has to be sent abroad. Similar problems arise for reference materials for chemical analysis, where capacities are lacking in some countries and provided services may be limited. Furthermore, accredited proficiency test providers are lacking in many areas, resulting in insufficient services for water testing laboratories. As a consequence, routine proficiency tests for water testing laboratories are not always undertaken, leaving testing laboratories without a key measure to compare and improve their capabilities.

In terms of *flow measurements*, calibration and verification services of macro flow meters for canals and distribution systems as well as micro flow meters at the point of consumption are required. The lack of calibration laboratories in water utilities in many countries and the lack of cheap solutions for macro meter calibration are some of the specific challenges to macro flow meter calibration (Johnson 2015). For household water meters (micro meters), national metrology institutes should provide traceability to drinking water providers, external calibration laboratories and inspection bodies, by organizing intercomparisons, calibrating reference water meters and calibrating test benches. Type approval services for micro flow meters are an important service to help water suppliers ensure quality of water metering at reduced cost.

The lack of quantification of water consumption is a big problem in many Sub-Saharan Africa cities. Many households do not have water meters. Where meters exist, they are frequently bypassed or manipulated by users to avoid water charges. Accurate water flow measurements are key for reducing non-revenue water, detecting leaks and illegal connections, extending coverage and ensuring a more efficient provision of water to consumers. Meter inaccuracies are one of two key components of apparent (commercial) losses in the International Water Association's water/non-revenue water balance (WASPA 2015). A functioning system for quantification of water backed by quality infrastructure services can lead to a more efficient use of water, which in turn helps to address the

problems of growing water scarcity in urban areas of Sub-Saharan Africa.

Finally, metrological services for the drinking water sector include the calibration of piezometers for the measurement of hydrostatic pressure used to monitor groundwater levels in wells. These are very important in the context of climate change in Sub-Saharan Africa, as many, particularly dry rural areas, are highly dependent on groundwater wells. Accurate information about remaining reserves can help people to better plan and take necessary measures long before prolonged drought-periods hit a region.

Standardization

International standards on drinking water and sanitation, determination of water quality and water flow, sampling procedures and wastewater systems form a solid framework for addressing global water challenges (see Table 9 for examples of relevant standards). National standards bodies play an important role in adopting these international standards into the national standards system. They adapt them to local conditions if necessary and develop national standards, if country-specific necessities arise, which are not covered by international standards. As a next step, awareness needs to be raised and the implementation of those standards promoted.

In addition to national standards bodies, regional and sub-regional standards institutions as for example the ARSO and the East African Standards Committee are also key in promoting the development and application of relevant standards. Regional standards can focus on concrete needs in Sub-Saharan Africa. The East African Standards Committee standards with relevance for the water sector were developed. Together with drinking water, water conveyance systems, containerized water, wastewater treatment and management of water systems have been at the focus in the past (EACS 2009). The development of regional standards for the adaptation to climate change of the water sector in Sub-Saharan Africa should be considered.

Furthermore, promoting participation of ARSO members and other stakeholders in international standardization processes is very important in order to have the Sub-Saharan African perspective better reflected in international standards. As climate change-related challenges in the water sector are becoming more and more visible, standardization efforts should also advance to support adaptation measures. Sub-Saharan Africa is a region which will be strongly affected and should ensure that newly developed international standards are applicable in the region.

ISO 10523:200 Water quality – Determination of pH
ISO 7027:1999 Water quality – Determination of turbidity
ISO 9308-1:2014 Water quality – Enumeration of <i>Escherichia coli</i> and coliform bacteria – Part 1: Membrane filtration method for waters with low bacterial background flora
WHO 2007 Guidelines for drinking water quality
ISO 4064-1:2014 Water meters for cold potable water and hot water
ISO 10508:2006 Plastics piping systems for hot and cold-water installations – Guidance for classification and design
ISO 24516-1:2016, Guidelines for the management of assets of water supply and wastewater systems – Part 1: Drinking water distribution networks
ISO 14046:2014 Environmental management – Water footprint – Principles, requirements and guidelines
EAS 15-1:2010, Methods of test for drinking water – Part 1–5
KS EAS 12:2014 Potable water – Specification
WHO Guidelines for drinking-water quality

Table 9: Examples of international, regional and national standards relevant for the water sector

Testing, certification and inspection

Testing in the water sector is performed by a variety of actors, such as water supply companies, public and private water testing laboratories and inspection authorities (environment and health).

The capacities of these institutions to perform testing of water quality are often deficient. In many laboratories for water quality monitoring in water supply companies, only few parameters such as turbidity, pH and alkalinity are monitored. For example, in Nairobi there are few water supply companies which monitor and analyse total organic carbon due to lack of instruments, in spite of the known problem of organic pollutants in drinking water (Wang et al. 2013).

An assessment of the performance of 72 institutions (water suppliers and public health agencies) across 10 countries in Sub-Saharan Africa found that most institutions did not achieve the testing levels specified by applicable standards or WHO Guidelines. Institutions operating in large urban areas with higher water quality budgets were more likely to meet testing targets than in smaller cities and rural areas. As a consequence, smaller water providers and rural public health offices have a greater need for resources in order to achieve regulatory compliance for water quality monitoring in Sub-Saharan Africa (Peletz et al. 2016).

In rural areas, drinking water quality is often tested by water users with field test kits, if at all. There, quality challenges relate to the capacity of the users to correctly make use of the test kits. Water quality assessment using bioindicators can be one option for evaluating the environmental health in stream and river water. This approach has already been applied with great success in rural communities and could serve as an alternative or addition to field test kits.

In industrial water management, the lack of procedures for wastewater monitoring including sampling is one among several other challenges (including lack of capacities, awareness, effective regulations and incentive schemes) which need to be addressed. In coastal areas, where desalinization treatment facilities play an important role, testing of salinity in the water for further use, for example at the household level, must be considered.

To strengthen available testing capacity in the water sector, networks of laboratories should be fostered. Accreditation according to ISO 17025 may be defined as a prerequisite for laboratories realizing analysis required in technical regulations (e.g. regulations on drinking water quality).

To ensure quality of services, water supply and sanitation companies as well as treatment plant operators can opt for certification of quality management (ISO 9001) and environmental management processes (ISO 14001). Certification processes can improve customer confidence, efficiency of water bill payments and drinking water service delivery.

Certification of field test kits for water quality may be of importance in countries where the network of laboratories is not dense enough to allow timely sampling and analysis for drinking water. This is particularly an issue in rural areas.

The inspection capacities in the water sector is an area with considerable potential for improvement in Sub-Saharan Africa. In the drinking water and sanitation sector, the inspection capacities of authorities to ensure compliance with environmental and health regulations are important for ensuring drinking water quality as well as protection of water bodies. This applies for environment, water and/or public health authorities in charge of monitoring compliance with water abstraction permits, drinking water quality, water meters (legal metrology) and service quality of the water supply and sanitation providers. In the sanitation sub-sector, relevant inspection capacities include compliance monitoring with regulations on treated and untreated wastewater discharges. In order to fulfil these functions, authorities need access to either in-house accredited testing laboratories or private laboratories. Inspector training is another common bottleneck, as is adequate pay of the inspectors to reduce corruption.

Accreditation

Internationally recognized accreditation allows testing and calibration laboratories as well as certification and inspection bodies to prove their technical competency. Accreditation according to the relevant international standard requires the conformity assessment body to have a quality management system in place and to follow international good practices in its activities. The water sector will be strongly affected by climate change. Extreme

weather events such as droughts and floods put pressure on water and sanitation systems. In many Sub-Saharan African countries, systems are not well prepared to withstand such pressures, which might affect water availability and quality.

For this reason, accreditation is a key element to ensure the reliability of the services of testing and calibration laboratories as well as inspection bodies in times of climate change, to monitor water quality and water levels and to generate accurate, timely information to allow for necessary adaptation measures to be taken in time.

Regulation/Transversal aspects

The drinking water sector must be governed by a set of technical regulations, which define the rules of the game of the public institutions (permits and inspections), service providers and user groups.

Regulations should include clear and measurable targets concerning water abstraction, use and discharge in line with international standards and tailored to local requirements. Regulations should also include indications about the type of controls and procedures which should be implemented to ensure quality of the services. For example, regulations on drinking water quality should be based on WHO norms, and the testing and inspection of the drinking water should be done by laboratories with a defined quality standard, for example through accreditation.

Clear regulations are also needed for the protection of catchment areas where water is abstracted for human consumption. This includes restrictions on land use, protection of riverbanks and other measures to safeguard ambient water quality.

The review and mainstreaming of quality parameters in technical regulations is an important prerequisite for the strengthening of water-related quality infrastructure institutions. Such regulations may include surface and groundwater protection including land use restrictions in catchment areas for drinking water efficiency and use, drinking water quality and sanitary infrastructure.

Links to other thematic areas of this study

The water sector has strong links to other sectors, such as health and agriculture, which are covered in other chapters of this report.

Water-related human health issues include vector-related and waterborne infectious diseases. Due to changes in the mean and variability of temperature and precipitation, their prevalence will change in terms of incidence and geographic range (IPCC, 2014). Quality infrastructure improvements in the water sector can prevent water-related health problems. For example, as a result of changing environmental and socioeconomic conditions, in previously malaria-free areas, particularly vulnerable groups are increasingly affected (Kienberger et al. 2014). Correct distribution and storage of water for human consumption can effectively reduce vector breeding of malaria. A quality infrastructure issue in this regard is the development of regionally adapted standards or technical regulations, providing guidance on the construction of water distribution and storage structures. Another example relates to faecally transmitted pathogens or diseases, such as cholera or schistosomiasis. To control these diseases, particularly in peri-urban slums or rural areas, an integrated approach including potable water and adequate sanitation services, backed by reliable quality infrastructure services is required.

For the agricultural sector in Sub-Saharan Africa, water availability is a determining factor. In peri-urban areas, farmers frequently irrigate vegetables for local markets with wastewater from nearby cities with considerable health risks for consumers and farm workers.

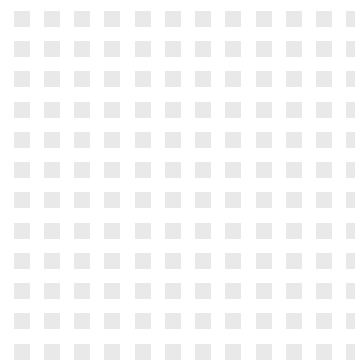
In regions with growing water scarcity, water insecurity may lead to conflicts between different water dependent sectors such as agriculture, industry and energy. Quality infrastructure services, which allow for a transparent accounting of water use and provide incentives for more efficient water use, can help address these conflicts and provide a basis for a more equitable distribution of water resources within and between sectors.

Definitions

Water intended for human consumption is defined as (modified from ISO 5667-5:2006): all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin.

Wastewater is defined as (modified from ISO 24511:2007): water arising from any combination of domestic, industrial or commercial activities, surface runoff and any accidental sewer inflow/infiltration water (which can include collected storm water), which is discharged to the environment or sewer.

Water security is defined as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being and social-economic development. Water security means that water sources are protected from water-borne pollution, that water-related disasters are prevented and that water-related ecosystems are preserved in a climate of peace and political stability (UN-Water 2015).



Quality infrastructure services/Value chain	Quality challenges	Metrology	Standardization	
Catchment (drinking water supply source)	■ Assessment of ambient water quality	<ul style="list-style-type: none"> ■ Equipment calibration ■ Chemical metrology 	<ul style="list-style-type: none"> ■ Site selection ■ Consideration of guidance documents/best practice 	
	■ Assessment of water availability/abstraction (surface/groundwater)	<ul style="list-style-type: none"> ■ Verification of macro and micro flow meters ■ Type approval of flow meters 		
Treatment	■ Control of treatment process	<ul style="list-style-type: none"> ■ Equipment calibration ■ Chemical metrology 	<ul style="list-style-type: none"> ■ System design ■ Water footprint considerations ■ Wastewater treatment quality considerations 	
Distribution/Storage	■ Control of storage/distribution systems	<ul style="list-style-type: none"> ■ Verification of macro and micro flow meters ■ Type approval of flow meters 		
Consumption	■ Monitoring of water use at household /endpoint	<ul style="list-style-type: none"> ■ Verification of macro and micro flow meters ■ Type approval of flow meters 	■ Wastewater & sanitation considerations	
	■ Assessment of water quality for human consumption	<ul style="list-style-type: none"> ■ Equipment calibration ■ Chemical metrology 		
	■ Customer service			

Table 10: Quality issues and necessary services of quality infrastructure along the value chain of drinking water supply



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	Testing	Certification	Inspection	Accreditation	Regulation/Transversal aspects
	<ul style="list-style-type: none"> ■ Testing of water quality parameters ■ Application of testing and sampling procedures ■ Testing of water flow 	<ul style="list-style-type: none"> ■ Environmental management systems ■ Water Footprint certification ■ Quality Management systems (e.g. ISO 9001) ■ Training and certification of water treatment operators ■ Certification of field test kits 	<ul style="list-style-type: none"> ■ Regular inspection of domestic water abstraction 	<ul style="list-style-type: none"> ■ Accreditation of water testing laboratories ■ Accreditation of calibration laboratories, certification and inspection bodies 	<ul style="list-style-type: none"> ■ Consideration of quality aspects and quality infrastructure services in water regulations ■ Definition of criteria on water quality and quantity ■ Definition of criteria for water efficiency and use, for sanitary infrastructure ■ Monitoring of criteria by accredited laboratories ■ Training and awareness raising about water quality and water use efficiency
			<ul style="list-style-type: none"> ■ Inspection of quality management of water treatment plants 		
			<ul style="list-style-type: none"> ■ Regular inspection of sanitary infrastructure quality ■ Inspection of quality management of water companies 		

Quality infrastructure services/Value chain	Quality challenges	Metrology	Standardization	
Wastewater & sanitary collection systems (domestic activities)	■ Functioning of collection system	<ul style="list-style-type: none"> ■ Equipment calibration ■ Chemical metrology ■ Verification of macro and micro flow meters ■ Type approval of flow meters 	<ul style="list-style-type: none"> ■ Wastewater & sanitation considerations ■ System design 	
	■ Control of industrial effluents			
Treatment	■ Control of treatment process	<ul style="list-style-type: none"> ■ Equipment calibration ■ Chemical metrology 	<ul style="list-style-type: none"> ■ System design ■ Water footprint considerations ■ Wastewater treatment quality considerations 	
Reuse or disposal in water bodies	■ Control of water pollution at point of discharge	<ul style="list-style-type: none"> ■ Equipment calibration ■ Chemical metrology ■ Verification of macro and micro flow meters ■ Type approval of flow meters 	<ul style="list-style-type: none"> ■ Site selection ■ Consideration of guidance documents/best practice 	
	■ Protection of water bodies			

Table 11: Quality issues and necessary services of quality infrastructure along the value chain of wastewater & sanitation

Quality infrastructure services/Value chain	Quality challenges	Metrology	Standardization	
Water abstraction	■ Assessment of ambient water quality	<ul style="list-style-type: none"> ■ Equipment calibration ■ Chemical metrology 	<ul style="list-style-type: none"> ■ Site selection ■ Consideration of guidance documents/best practice 	
	■ Assessment of water availability/abstraction	<ul style="list-style-type: none"> ■ Verification of macro and micro flow meters ■ Type approval of flow meters and other equipment 		
Treatment	■ Control of treatment process	■ Equipment calibration	<ul style="list-style-type: none"> ■ System design ■ Water footprint considerations ■ Wastewater treatment quality considerations 	
Process water control	■ Control of water quantity and quality	<ul style="list-style-type: none"> ■ Equipment calibration ■ Chemical metrology 		
Wastewater treatment and reuse	■ Functioning of collection system	<ul style="list-style-type: none"> ■ Verification of macro and micro flow meters ■ Type approval of flow meters 		
	■ Control of treatment process	■ Equipment calibration		
Reuse or disposal in water bodies	■ Control of effluent quality at point of discharge	<ul style="list-style-type: none"> ■ Equipment calibration ■ Chemical metrology 	<ul style="list-style-type: none"> ■ Site selection ■ Consideration of guidance documents/best practice 	

Table 12: Quality issues and necessary services of quality infrastructure along the value chain of industrial water management

	Testing	Certification	Inspection	Accreditation	Regulation/Transversal aspects
	<ul style="list-style-type: none"> ■ Testing of water quality parameters ■ Application of testing and sampling procedures ■ Testing of water flow 	<ul style="list-style-type: none"> ■ Environmental Management systems ■ Water Footprint certification ■ Quality Management systems (e.g. ISO 9001) ■ Training and certification of water treatment operators ■ Certification of field test kits 	<ul style="list-style-type: none"> ■ Regular inspection of sanitary infrastructure quality ■ Inspection of quality management of water companies 	<ul style="list-style-type: none"> ■ Accreditation of water testing laboratories ■ Accreditation of calibration laboratories, certification and inspection bodies 	<ul style="list-style-type: none"> ■ Consideration of quality aspects and quality infrastructure services in water regulations ■ Definition of criteria on water quality and quantity ■ Definition of criteria for water efficiency and use, for sanitary infrastructure ■ Criteria are monitored by accredited laboratories ■ Training and awareness raising about water quality and water use efficiency
			<ul style="list-style-type: none"> ■ Inspection of quality management of water treatment plants 		
			<ul style="list-style-type: none"> ■ Regular inspection of wastewater discharge 		

	Testing	Certification	Inspection	Accreditation	Regulation/Transversal aspects
	<ul style="list-style-type: none"> ■ Testing of water quality parameters ■ Application of testing and sampling procedures ■ Testing of water flow 	<ul style="list-style-type: none"> ■ Environmental Management systems ■ Water Footprint certification ■ Quality Management systems (e.g. ISO 9001) ■ Training and certification of water treatment operators 	<ul style="list-style-type: none"> ■ Regular inspection of industrial water abstraction 	<ul style="list-style-type: none"> ■ Accreditation of water testing laboratories ■ Accreditation of calibration laboratories, certification and inspection bodies 	<ul style="list-style-type: none"> ■ Consideration of quality aspects and quality infrastructure services in water regulations ■ Definition of criteria on water quality and quantity ■ Definition of criteria for water efficiency and sanitary infrastructure ■ Criteria are monitored by accredited laboratories ■ Training and awareness raising about water quality and water use efficiency
			<ul style="list-style-type: none"> ■ Inspection of quality management of water treatment plants 		
			<ul style="list-style-type: none"> ■ Regular inspection of industrial wastewater discharge 		

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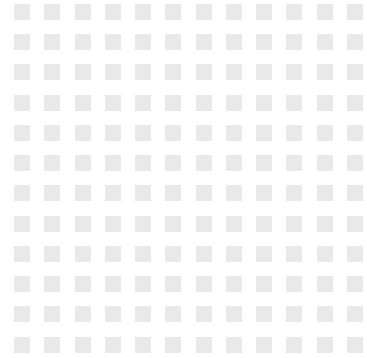
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2.6. Human health

Author: Carmen Anthonj

2.6.1. Current trends in the sector in times of climate change (global and regional)

Human health and well-being are closely linked to climate change and influenced both by its direct and indirect effects. Changing temperature and rainfall patterns, sea level rise, an increase in extreme weather events, the intensity and frequency of floods and storms, drought and heat stress cost lives, cause injuries and increase the risk of transmission of infectious, respiratory and cardiovascular diseases. Moreover, extreme events such as flooding and storm surges can cause destruction of houses and assets among affected communities, lead to a loss of property, land and livelihoods and thereby increase the prevalence of mental illness. Additionally, climate change affects ecosystems and particular species. It can facilitate microbial proliferation, degrade air and water quality and result in unsafe drinking water and food poisoning, with both of the latter increasing the prevalence of waterborne diseases such as diarrhoeal diseases and cholera. Land use changes and ecological modifications change vector-pathogen-host relations and infectious disease geography and seasonality, thereby facilitating the spread of vector-related and water-based diseases such as malaria, schistosomiasis and dengue fever. Moreover, changes in climatic conditions, land use changes and the degradation of the environment, land and water bodies

and coastal ecosystems lead to a loss of livelihoods, crops, livestock and fishery yields, thereby impairing nutrition and causing food insecurity, mal- and undernutrition and other adverse health effects. The same implications arise from salination of coastal land and freshwater and storm surges, all resulting from climate change-induced sea level rise. Consequently, migration and the displacement of affected communities lead to poverty and the spread of infectious diseases, malnutrition and mental health effects, along with physical risks (Watts et al. 2015, Smith et al. 2014).

According to the World Health Organization (WHO), between 2030 and 2050 global climate change is expected to cause 250,000 additional deaths annually due to malaria, malnutrition and diarrhoea, heat stress and water scarcity, whether in rural communities, small island and coastal towns or in big cities (McMichael et al. 2006, Haines et al. 2006, WHO 2015a, 2015b).

Extreme events resulting from climate change not only lead to an increased burden of disease, but climate change potentially adversely affects the ability of health system institutions and organizations to maintain their service. Flooding, for example, may cause the inaccessibility and destruction of health services and health infrastructure, changing temperature may make medical laboratories and devices inoperative (WHO & HCWH 2008, WHO 2015b). This causes a double health burden to the affected communities which are faced with more diseases, but less ability to respond.

Concurrently, policy and technology choices which drive climate change (polluting energy sources and unsustain-

Effect	Floods	Flash floods/tsunamis	Drought
Deaths	Few	Many	Many
Severe injuries	Few	Few	Few
Communicable diseases	Varies*	Varies*	Many
Food scarcity	Varies*	Common**	Common**
Major population displacements	Common**	Varies*	Varies*
Own compilation with data from the Sphere Project (2011) and McMichael et al. (2003). The categorization 'varies*' means that depending on the severity of extreme event, the health outcome differs. 'Common' means that under the named extreme event, the respective health outcome usually occurs.			

Table 13: Public health impact of selected extreme events

able transport systems) have health impacts, which is why the need to “integrate health issues in all climate change mitigation and adaptation measures, policies and strategies at all levels and in all levels” was previously formulated in the Parma Declaration of 2010 and its Commitment to Act (WHO 2016b) (Annex 2).

Sub-Saharan African communities are greatly exposed to climate change-related extreme events, as is described in the WHO & UNFCCC Climate and Health Country Profiles for Botswana, Ethiopia, Kenya, Ghana, Madagascar, Nigeria, South Africa, Tanzania and Uganda (WHO & UNFCCC 2015, 2016)¹⁷. According to this source, the region faces changing temperature and rainfall patterns, an increase in extreme weather events, the intensity and frequency of floods and an increased risk of drought and heat stress. All of these implications are associated with adverse health effects. In all of the countries listed, vector-borne diseases such as malaria, dengue and yellow fever will increase due to changing climate conditions. Moreover, waterborne diseases such as diarrhoeal diseases and cholera are on the rise, especially where increased flooding is projected. The proportion of diarrhoeal deaths in children¹⁸ attributable to climate change will increase, as well. Water-based diseases such as the neglected tropical disease schistosomiasis are predicted to spread. Increased temperature will result in nutritional and water insecurity and in heat-related deaths in elderly (65+ years of age) persons; outdoor air pollution is predicted to increase mortality from respiratory infections in all countries in the region. Besides these direct health effects in Sub-Saharan Africa, populations will need to be displaced due to flooding, with potential adverse health effects on their mental well-being.

These strains on the health systems are highly problematic given that Sub-Saharan African countries carry the largest burden of health threats resulting from climate change, while at the same time already having the weakest healthcare systems and the lowest access to healthcare and health-related services globally. Considering the climate change-related trends and the projected high and potentially catastrophic risks to human health, there is the strong need to strengthen the health systems in countries across Sub-Saharan Africa. Stronger and more climate resilient health systems, to be achieved by mitigation and

adaptation responses, can save lives and protect humans from future climate risks and reduce the burden and growing cost of diseases. In some countries of Sub-Saharan Africa, numerous actions are being taken already. For instance, Ethiopia, Kenya and Madagascar have conducted national assessments of climate change. Special programmes on health in the context of climate change are being implemented by Kenya in terms of a Malaria Early Warning System, the Project Climate Health in collaboration with the World Meteorological Organization (WMO) in Madagascar and the South African Adaptation Scenarios Flagship, a long-term programme aimed at developing adaptation strategies.

The SDG 3 seeks to ensure health and well-being for all, at every stage of life. The goal addresses all major health priorities, including those particularly important in the context of climate change, such as communicable, non-communicable and environmental diseases; universal health coverage; and access for all to safe, effective, quality and affordable medicines and vaccines. It also calls for more research and development, increased health financing and strengthened capacity of all countries in health risk reduction and management. All health services should be strengthened, given that human health is a precondition for economic growth and development (SDG 8) and poverty reduction (SDG 1).

On a global level, the incidence of major infectious diseases such as malaria, the maternal mortality ratio, the under-five mortality rate, deaths caused by non-communicable diseases such as cardiovascular diseases, cancer and respiratory diseases and other health conditions has declined. However, they still largely occur and are projected to increase in Sub-Saharan Africa. Many of the diseases could be prevented with better health infrastructure and environmental conditions (including water, sanitation and hygiene as formulated in SDG 6 and as elaborated in section 2.5 (water).

In Sub-Saharan Africa, the demographic estimates (Annex 3) indicate fast population growth with a large share of population below the age of 5 and a high share of the population living in rural areas with potentially limited health access. Adverse health effects hit those hardest who are disadvantaged economically and in terms of development indicators –especially people in Sub-Saharan Africa.

¹⁷ Additional information can be found in Annex 3.

¹⁸ This is of high relevance because children, as well as the elderly, are the ones most vulnerable to the effects of climate change.

Against the backdrop of climate change and the health trends entailed, strengthening the health sector is crucial because protecting human health and preventing diseases and death is a goal on the Sustainable Development Agenda. According to Watts et al. (2015), **tackling climate change could be the greatest global health opportunity of this century.**

The predicted high burden of diseases in the course of climate change and low health indicators¹⁹ underline the importance of developing quality infrastructure services which ensure the quality in health systems in Sub-Saharan Africa.

2.6.2. Significance of quality infrastructure services

To effectively protect human health and contribute to the SDGs (especially goal 3 “good health and well-being”) in times of climate change, the health sector needs to adapt its services, products, systems and processes to the health trends described above. The required adaptations include the following:

- Development of new services and products to prevent, treat and oversee new emerging or the further spread of diseases
- Quality assurance of existing information, products and services which are being currently used
- Increase of the health sector efficiency, in order to be able to meet the increased demand for medical services and products
- Adaptation of the sector’s infrastructure, organizational structures and processes to the impacts of climate change

These adaptations require systematic quality management in the sector to fulfil the objective of protecting human health in times of climate change. In this context, quality management can be understood as defined in ISO 9001:2015. The standard includes the concept of adaptation to risks which have to be systematically identified and considered in a continuous improvement process.

¹⁹ Health indicators for Sub-Saharan Africa: low life expectancy at birth, high under-five mortality per 1,000 live births and a high prevalence of child malnutrition under the age of 5.

Climate change results in severe risks in the understanding of the standard, for both the health sector and its clients.

Quality infrastructure provides the services required for a systematic quality management in the sector. For this reason, its contribution is fundamental for the adaptation of the health sector in Sub-Saharan Africa to climate change. The contributions of the components of quality infrastructure may be summarized as follows:

- *Metrology*: Provides calibration, intercomparison measurements and reference material required by medical laboratories, secondary calibration laboratories, the medical industry and users of testing equipment in the sector. Metrological services are fundamental to ensure traceability and to increase the exactitude of tests and measurements in the sector. They become increasingly important in times of climate change in Sub-Saharan Africa, as they provide the basis for reliable medical information and the assurance of quality of services and products.
- *Standardization*: Provides commonly agreed criteria for medical services, products, processes and systems. Standardization creates the basis for efficient processes and an effective quality management. Additionally, by considering the specific climatic conditions in Sub-Saharan Africa, standards can foster the adaptation of the health sector.
- *Testing, Certification and Inspection*: These are required to ensure conformity of medical products, systems and personnel with quality criteria. The related services are increasingly important in times of climate change in Sub-Saharan Africa, as reliable and timely information on the health status of individuals and the population is needed to facilitate timely and correct medical decisions. Certifications and inspections confirm compliance of personnel, products, services and systems with standards and regulations. Certification and inspection services provide information for the quality management in the sector and are crucial for the protection of human health.
- *Accreditation*: Assures the technical competence of laboratories, certification and inspection bodies. The assurance of reliable metrology and conformity assessment is crucial, as decisions on health treatments

are made based on the results of these services. Given that climate change is predicted to increase the burden of poor health, the sector's ability to respond is of high importance. In addition, accreditation confirms the reliability of information for the detection of the most pressing climate change-related diseases.

- *Regulation and transversal aspects:* The national regulations need to define quality criteria for health services and products. Appropriate systems and governance structures need to be created for the registration of medicines and for effective market surveillance. In this context, a key issue in Sub-Saharan Africa is the poor quality of medicines on the market, estimated to represent 34% of the total medicines used (Giralt et al. 2017). Given that in times of climate change more and new medicines will be used, appropriate regulations and market surveillance mechanisms to reduce the market share of poor quality medicines will become even more important than they are today.

The adaptation of the medical sector to climate change requires a systematic and holistic development of the quality infrastructure services needed. An important example in this context is market surveillance to reduce the market share of poor quality medicines. The effective control of medicines requires appropriate regulations and governance structures, but also services of metrological and testing laboratories, inspection and accreditation bodies based on international standards.

2.6.3. Identification of sub-sectors relevant in Sub-Saharan Africa

The selection of sub-sectors of human health for this study is based upon their relevance for Sub-Saharan Africa and, in times of climate change, their relevance for the achievement of the SDGs.

Medical laboratories, the backbone of medical prevention, diagnosis and treatment, primarily influence health care decisions (Zima 2010). They serve for the examination of (micro)biological, immunological, chemical, (immune) haematological, biophysical, cytological, pathological and other material stemming from the human body in order to gather information for the prevention, diagnosis and

treatment of diseases or the assessment of human health. The main services provided and relevant in Sub-Saharan Africa include the analysis of samples and results and advice regarding consecutive examinations (WHO 2016). The most common communicable diseases can be diagnosed clinically (diarrhoea, acute respiratory infections), with the assistance of rapid diagnostic tests or with microscopy (e.g. malaria). Additionally, medical laboratories can confirm causes of a suspected outbreak and assist case management decisions (e.g. dysentery) and the selection of vaccines for mass immunization by providing testing for culture and antibiotic sensitivity. Moreover, for certain non-communicable diseases, laboratory testing is essential for diagnosis and treatment (Sphere Project 2011). The adequate services of medical laboratories are of high importance and include health status assessment and correct diagnosis through exams, a clear identification of patients, collecting and transporting samples, processing and investigating up to validation and evaluation, safety and ethics issues, the responsible handling of samples as well as their correct archiving and the disposal of infectious samples and hazardous reagents. Medical laboratory infrastructure determines the reliability of analyses and ensures the safety of patients and staff (WHO 2015a, 2016). Facing an increased burden of disease in the course of climate change, quality infrastructure services for medical laboratories become ever more important in Sub-Saharan Africa.

In order to detect disease outbreaks and epidemics in good time and early enough to prevent a rapid spread, the results need to be reliable not only for the individual patient, but also comparable on an international level. However, at present, most of the medical laboratories in Sub-Saharan Africa do not provide sufficient and exact analytical results.²⁰ Thus, as a result, many medical centres base their treatment decisions on clinical judgment and empiric diagnoses (Elbireer et al. 2011). In some Sub-Saharan African countries, lacking quality assurance (Schroeder & Amukele 2014) and mistrust in the medical laboratory services provided leads to a situation where clients consult different laboratories for the same kind of analysis, in order to then consider a middle value as valid.

²⁰ As found in a study of medical laboratories in Kampala, Uganda, out of the 954 laboratories in the city, only 5% of laboratories met even the lowest quality standards as defined by WHO, and only 0.3% met the requirements for an accreditation (Schroeder and Amukele 2014).

This potentially results in misdiagnoses and improper medication use which leads to health risks and wasted resources due to inappropriate treatment.

Medication will be increasingly important in Sub-Saharan Africa, as short-term and long-term climate change effects make communities increasingly sick. More and potentially new medication will be needed in order to respond to the increasing burden of diseases.

At present, the adverse reactions of low quality drugs and medication errors pose severe health threats in Sub-Saharan Africa. About 70 % of the drugs distributed in Sub-Saharan Africa are imported and there is a risk of poor quality medicine entering the supply chain. Although counterfeit medicines and poor quality medicines are in circulation in Africa, only 20 % of the countries test samples for post-marketing surveillance (SPS 2017). In 2010, 90 % of the National Medicines Regulatory Authorities (NMRAs) did not enforce basic regulatory functions, implying major threats for individual and public health (Giralt et al. 2017). Considering this, market surveillance and transportation conditions must be improved.

Health reporting is an important instrument for disease prevention as well as outbreak and emergency management (WHO 2015b, 2016). Integrated disease surveillance, response and early warning (rapid diagnostics, risk mapping), monitoring and communication strategies are vital in order to develop adequate capacity and flexibility to understand the links between climate and disease, allowing groups to anticipate changing risks and informing preparedness, surveillance and response in a timely manner (WHO 2015a). Health information can consist of various data sources such as mortality statistics, specific clinical registries, administrative databases, electronic health records and surveys conducted on specific patient groups or households (OECD 2017). However, such programmes are often constrained by limited human and financial resources, especially in developing countries. By receiving, securing, processing, provisioning and releasing disease data, (electronic) health information systems are critical for detecting trends in any health outcome and for identifying outbreaks early enough for effective interventions. Improving surveillance and monitoring is often a highly successful approach to increasing knowledge of the geographic range, seasonality and incidence of climate-sensitive health outcomes (WHO 2015a, b), thus providing opportunities for mitigating the adverse health impacts

arising from climate change (Stoldt et al. 2015). Systems aiming to optimize disease surveillance are in place in some countries, e.g. the use of handheld computers or mobile phones to rapidly send and receive data on malaria cases from remote health units are in use in Tanzania (Sevir 2013, Cox 2009). However, they are not comprehensive.

So far, such health information systems rarely follow any agreed standards, even though harmonized, exact and coordinated data collection and reporting is of high importance in order to control disease. At present, reporting mechanisms in Sub-Saharan Africa are insufficient, which is why the WHO is aiming at implementing integrated disease surveillance and response (IDSR) programmes (Isere et al. 2015). This gives a suitable entry point and shows the high relevance of quality infrastructure in health reporting to develop and expand respective quality infrastructure services.

2.6.4. Demand of quality infrastructure services in Sub-Saharan Africa for the identified sub-sectors

Medical laboratories

In times of climate change in Sub-Saharan Africa, quick and reliable laboratory results are of key importance to detect diseases in a timely manner and to take the correct decisions to protect public and the patients' health. Quality infrastructure services are needed to implement quality management procedures and thus to ensure reliable results of medical laboratories.

Besides, as is also the case in other laboratories, medical laboratory infrastructure will face several challenges with regard to climate change and related extreme events such as flooding, heat waves and drought. The latter might have destructive effects on the laboratories' manufacturing components, on the transport of equipment, the installation of a laboratory and its operation. Overall, extreme events might leave laboratories inaccessible, destroy or disrupt their services, their access to safe water, sewerage infrastructure, sufficient energy and IT services needed in order to meet the sector's demands. Quality infrastructure may support medical laboratories to be better prepared for the effects of climate change, e.g. by improving the monitoring of climatic conditions. The related demand for services of quality infrastructure is described

in more detail in the following section.

In this context, it must be considered that new global scale medical testing methods are emerging, which will radically change the current practice of laboratory testing. An example of these trends is the field of theranostics, where diagnostics and therapy are combined based on nanotechnologies. A "lab on a chip" is a miniaturized device which integrates several laboratory functions on a nanochip. It enables the use of small fluid volumes and allows greater control over sample concentrations and thus provides potential in terms of early and point of care diagnostics with low cost, low sample volumes, ease and very limited chemical waste. Labs on a chip can be used to detect microorganisms which cause diseases such as malaria, dengue, diarrhoea, tuberculosis, pertussis and others (Cheriyedath 2015, Schmidt et al. 2014).

Even though these technologies are being developed mainly outside of Sub-Saharan Africa at present, they will also become relevant for the region in the future and will likely be very important for tackling new health issues in times of climate change. For this reason, the requirements of these new approaches for quality infrastructure services should be evaluated.

Metrology

At present, equipment calibration is lacking in many testing laboratories in Sub-Saharan Africa. This is especially an issue in many public laboratories, whereas private laboratories often opt for an accreditation, requiring the calibration of equipment.

Lacking equipment calibration leads to unreliable results of laboratory analysis. This is a common problem in the health sector in Sub-Saharan Africa, but in the context of climate change (as stated above) it becomes even more relevant to achieve reliable and internationally comparable results in a timely manner.

For this reason, it is important that national metrology institutes offer the calibration of basic laboratory equipment and that they have sufficient capacities to calibrate equipment in a timely manner. More advanced national metrology institutes should provide traceability to secondary calibration laboratories which offer calibrations to medical laboratories. Volume (e.g. of pipettes), mass and temperature can be seen as basic calibration services in this context. If these services are not available nationally

at present, it is advisable to establish relationships with calibration laboratories in neighbouring countries. In this way, the demand can be met and costs are lower than when services in more distant countries, for example in Europe, must be used. In the long run, however, the focus should lie on developing the services to calibrate the relevant equipment for volume, mass and temperature in the country, considering the amount of calibrations needed and the necessary turnaround time of calibration carried out abroad. Additionally, providing traceability in the area of humidity will be increasingly important in times of climate change in Sub-Saharan Africa and should be seen as further priority area in terms of development.

Other calibrations, for example the calibration of spectrometers or centrifuges, are used less frequently. Depending on the concrete national demand, related calibration services do not have to be offered on a national level, but can also be provided by a calibration laboratory of another country in the region. In any case, it is important that the national metrology institute provides access to the relevant calibration services, either by offering its own services or by providing contacts to other calibration laboratories.

In the area of chemical metrology, the more advanced national metrology institutes of Sub-Saharan Africa offer certified reference material and proficiency tests which are also relevant for medical laboratories. Reference material and proficiency tests are also offered by other, mainly private, providers in the region. Considering the required investments and a relatively low demand in most countries in Sub-Saharan Africa, it seems more important that national metrology institutes provide information and the necessary contacts to providers of these services than establishing these services on their own.

Standardization

Many of the medical laboratories in Sub-Saharan Africa do not apply the relevant international standards and guidance documents.

In the first place, this is relevant for quality management according to the particular requirements for quality and competence in medical laboratories as suggested in the ISO 15189:2012. The standard is currently under revision and will most likely include the risk concept defined in the ISO 9001:2015 (see subsection 2.6.2). The medical sector should already consider this concept now in its

quality management. The WHO and TDR Guidelines on Good Laboratory Practice moreover provide guidance on the quality upgrade of laboratories. In times of climate change, the quality management of medical laboratories becomes even more important than it is today. For example, higher temperatures and humidity will result in the increasing importance of appropriate sample storage.

Given the increased risk of extreme weather events and their possible effects on the medical laboratory infrastructure, it is especially important to apply the requirements of ISO 15189:2012 on adequate environmental conditions in the planning and installation of a medical laboratory. Climate-proof planning includes energy supply, lighting, air conditioning, water, sanitation and sewerage, the safeguarding of hygiene standards, the prevention of dust, humidity and other disturbances and also finding the correct location (WHO 2015a) to protect the facility e.g. from flooding as specifically elaborated in the Sphere Guidelines. In this context, the adaptation of the international standards and guidance documents to specific national conditions and the elaboration of national implementation guidance documents which consider local environmental conditions may be useful.

The installation process should follow the ISO 15189:2012 instructions on work safety and the WHO and TDR Guidelines. The same standard determines the accurate transport, storage, processing and analysis of laboratory samples.

Information about the relevant standards and the promotion of their application (e.g. via the elaboration of specific national guidance documents) is vital. Moreover, trainings on their implementation should be offered and standards should be referenced in national policies.

Testing, certification and inspection

Medical laboratories should conduct medical tests according to ISO 15189:2012 and (if possible) have an internationally recognized accreditation, based on accredited calibration services. To provide reliable results, medical laboratories require tests of their environmental conditions, for example of water quality and meteorological parameters. These tests become more important in times of climate change, as environmental conditions become both more extreme and more unpredictable. In the planning phase, such tests may help to overcome climate change-related challenges in the environmental conditions of medical laboratories. Such tests of the en-

vironmental conditions should be performed applying the relevant standards, especially ISO 17025.

In the area of certification, especially the certification of laboratory personnel is relevant in this context. Specific certification schemes to ensure the technical competence of the personnel of medical laboratories exist internationally,²¹ but in the scope of this study no specific examples in Sub-Saharan Africa could be identified. Such schemes can significantly increase the reliability of the laboratory results.

In many Sub-Saharan African countries, the Ministries of Health are responsible for inspections according to the national regulations related to medical laboratories. In practice, inspections are often not realized due to lacking capacities. Considering the relevance of quality assurance in medical laboratories in times of climate change, it seems important to increase capacities and competencies for effective inspections of medical laboratories. Not only the general quality management, but also specific inspection schemes for storage facilities, transportation services, infrastructure safety, disposal services (infectious samples and hazardous reagents and material) and commissioning procedures of newly installed laboratories need to be in place in order to prepare the installations for the adverse effects of climate change.²² Moreover, border inspections of imported pharmaceuticals and reagents need to be conducted in medical laboratories.

Accreditation

Taking into consideration the effects of climate change on human health in Sub-Saharan Africa, the assurance of the technical and medical competence of medical laboratories by an accreditation based on ISO 15189:2012 becomes especially important. This is due to the following:

- **Reliability for appropriate medical decisions:** In times of the increasing burden and transmission of diseases due to climate change, quick and timely access to reliable health analyses is a key element to take appropriate medical decisions for the patients. The accreditation ensures the technical competence and the reliability of the information.

²¹ This is offered, for example, by the ASCP Board of Certification (BOC) in the USA. It is available at: <https://www.ascp.org/content/board-of-certification/getcertified>, last access 01.08.2017.

²² The Checklist Standard for Medical Laboratory as suggested by the WHO could be applied for this.

- **Reliability for health monitoring:** Effective and efficient health monitoring and surveillance require common quality assurance procedures by the accreditation of medical laboratories. This is relevant on the national as well as on the international level. In terms of the latter, the comparability of data on clinical tests is even more important in order to use this information for the prevention, management and control of the spread of diseases.

In many countries of Sub-Saharan Africa, accredited medical laboratories are mainly lacking in the public sector. According to Schroeder and Amukele (2014), 37 out of 49 countries had no laboratories accredited to international

quality standards (see also Figure 4).²³ This means that especially for lower income population groups – which will be especially affected by climate change – the reliability of clinical analyses is not always ensured. Moreover, the reliability of health monitoring data based on unaccredited public laboratories may be questioned.

At present, in many countries in Sub-Saharan Africa, accreditation bodies are lacking. Only few accreditation bodies offer the accreditation of medical laboratories and only one of them, the accreditation body of South Africa, is recognized by the International Laboratory Accreditation Cooperation (ILAC) for this service. This increases the

²³ To interpret the relatively high numbers of accredited medical laboratories indicated in the figure for some countries (especially South Africa), it must be considered that also partial accreditations and accreditations of different laboratories of the same organization are counted.

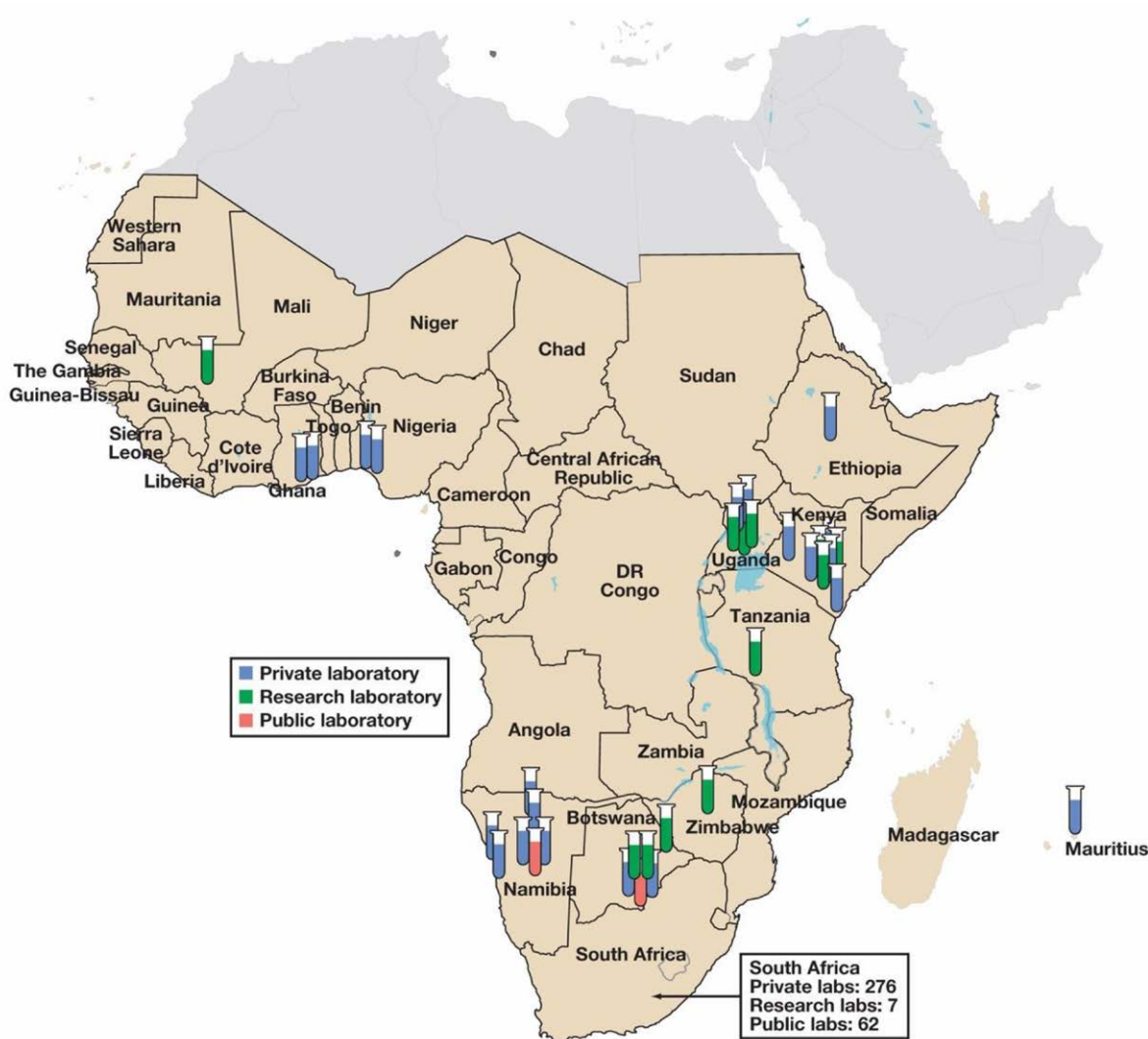


Figure 4: Accredited medical laboratories in Sub-Saharan Africa (Schroeder and Amukele 2014)

costs for the accreditation of medical laboratories which thus need to be conducted by foreign accreditation bodies. The establishment of accreditation bodies becomes even more important in times of climate change. As the establishment of an accreditation body takes several years, especially medical reference laboratories could be accredited for an intermediate phase by foreign accreditation bodies. This approach could be expanded to include further medical laboratories.

An internationally recognized accreditation is especially important for international health monitoring and the exchange of related health and disease data. National clinical reference laboratories could be accredited in a peer evaluation with internationally recognized bodies. Additionally, proficiency test providers and reference material producers should be accredited.

Regulation/Transversal aspects

Considering the importance of medical laboratories in times of climate change for the protection of human health and for the prevention of diseases and epidemics, criteria for quality assurance should be included in the most relevant technical regulations. This may include, for example, the accreditation of public medical laboratories. Quality criteria should further be included in the commissioning procedures for medical laboratories, completed by inspection and verification schemes for medical laboratory equipment, both with reference to international standards.

A key measure to improve the reliability of medical laboratory tests is the organization of proficiency tests. They should be organized nationally and regionally. The organization of laboratories in networks can, among other things, contribute to organizing proficiency tests at lower prices than they are offered to individual laboratories.

The effective improvement of quality assurance furthermore requires the inclusion of the topic in public policies, awareness raising activities and training programmes. Moreover, aspects of disaster management should be integrated into any quality assurance processes.

Medication

As stated before, given the low percentage of medication produced in Africa, the main contribution of quality infrastructure in this area may be seen in guaranteeing the market surveillance of imported medicines. This will be

increasingly important in times of climate change, which

- cause the increased burden of diseases and thus, the increased demand for (new) medicine and
- induce changes in temperature and humidity, which have the potential to adversely affect the medical effectiveness and curative power of drugs.

Additionally, new emerging infectious diseases and the more rapid spread and higher prevalence of diseases will require the import of more and new medicine, requiring additional quality infrastructure capacities.

Considering this, the improvement of the existing practice of quality assurance of medication in Sub-Saharan Africa is critical, particularly when taking into account that according to a WHO assessment of 26 national medical regulatory authorities in Sub-Saharan Africa, 54 % have no quality monitoring system, only 27 % test in case of complaints or as part of specific programs and only 19 % have systematic programs in place (SPS 2011).

Official medicines control laboratories exist in most countries of Sub-Saharan Africa. They act on behalf of the regulatory authorities. They retest the quality of medicinal products independently from the manufacturers. As they play a key role in the protection of human health, quality assurance is especially important in these laboratories.

Metrology

Metrological services for medication in times of climate change have to focus on the needs of official medicines control laboratories involved in the quality monitoring of medicines as well as on the environmental conditions during transport and storage.

Considering the increasingly important role of official medicines control laboratories in ensuring the quality of medicines in times of climate change, the assurance of the traceability of the tests conducted is fundamental. In this context, national metrology institutes in many countries of Sub-Saharan Africa have the potential to offer basic calibration services to the official medicines control laboratories (for example, in the areas of temperature, mass and volume). Metrology services which are not offered nationally may potentially be provided by other national metrology institutes in Africa. A systematic assessment of the needs for metrological services of the official medicines control laboratories as well as the coordination of

national metrology institutes which could serve as providers of these services could be realized by the regional or sub-regional metrology associations (for example the Southern African Development Community Cooperation in Measurement Traceability – SADCMET) or the Intra-Africa Metrology System (AFRIMETS).

At present, new global scale testing methods are emerging, for example initiatives like the use of handheld near-infrared and Raman spectroscopies. These methods are especially interesting for Sub-Saharan Africa, as some of them allow for a quick analysis of medicines outside of laboratories (for example, during import) (SPS 2011). Leading laboratories in Sub-Saharan Africa have developed innovative approaches with this regard (see for example ICRAF in section 3.1. on Kenya). These lead to changes in the demand for calibration services and reference material, which should be considered in assessments conducted by the relevant metrology associations.

In terms of environmental conditions during transport and storage, the principle parameters to be considered include humidity and temperature (see also explanations above in the “Medical laboratories” section). In this field, as is the case in the official medicines control laboratories, the demand for metrological services largely depends on the awareness level and on the policies of the national medical regulatory authorities. In this context, it is important to foster the communication and cooperation between institutions involved in the monitoring of the quality of medicines and the metrology organizations, at the national as well as at regional and sub-regional levels.

Standardization

In the area of standardization, there are several international standards which define aspects like substances, product information and dose form (ISO 11238, ISO 11615, ISO 11239). Considering the important changes in the environmental conditions in Sub-Saharan Africa in times of climate change, especially temperature and humidity, the development of specific international or national standards on the transport and storage of medicines under these specific conditions should be considered. Also, it should be reviewed if the existing international standards are applicable to new medicines developed for the conditions in Sub-Saharan Africa (McMichael et al. 2003). In this context, it is important that the standardization bodies in Sub-Saharan Africa are represented in the relevant international technical committees to include

their specific needs in international standardization processes. Additionally, in (preferably) regional or national initiatives it should be evaluated if the adaptation of international standards to the specific conditions, considering future changes in Sub-Saharan Africa, is necessary.

Testing, certification and inspection

Official medicines control laboratories must provide the services required for an effective market surveillance of the most relevant medicines, as well as ensure the reliability of results. However, at present, the laboratories in many countries in Sub-Saharan Africa are lacking both the relevant services required and effective quality management systems. For this reason, the reliability of the tests conducted by the official medicines control laboratories for the initial verification of the medicines during the national registration process as well as for the subsequent monitoring of the quality of medicines is not guaranteed. Given the need for additional important medicines, the risk of unreliable laboratory services will increase for individuals and public health in times of climate change.

In order to eliminate substandard and counterfeit medicines and to improve the monitoring of the quality of medical products, the WHO has supported official medicines control laboratories in Africa and “prequalified” them (WHO n.d.; the study did not disclose the criteria underlying this prequalification). The support of official medicine control laboratories in the process of implementing the relevant international standards and in achieving an internationally recognized accreditation could ideally be extended and improve a network of laboratories which might also be used as a reference for other countries, such as the networks of official medicines control laboratories (OMCLs²⁴), of which the African NOMCoL network covers several Sub-Saharan African countries. Such networks can significantly improve the monitoring of the quality of medical products in Sub-Saharan Africa.

²⁴ OMCL networks were established to provide a forum for sharing best practices on medicine quality issues at regional and national levels. They offer inter-laboratory testing activities for participating labs to improve laboratory performance as well as harmonize their drug analysis methodologies. They aim to strengthen the performance and technical skills of staff, promote communication and the exchange of information, harmonize methodologies to facilitate acceptance/recognition, ensure compliance with Good Laboratory Practices (GLP) and help eliminate substandard and counterfeit drugs. The African network covers Botswana, Burundi, Cote d'Ivoire, Ethiopia, Ghana, Kenya, Liberia, Mali, Mozambique, Nigeria, Senegal, Sierra Leone, Tanzania, Uganda, Zambia and Zimbabwe (USP 2017).

The national medicines regulatory authorities handle and are charged with safeguarding the inspection of manufacturers, importers, exporters, wholesalers, distributors and pharmacies. These authorities, however, lack appropriate regulations, structures, processes and resources to fulfil this task in many Sub-Saharan African countries. These known deficits will likely result in increasing health risks in Sub-Saharan Africa in times of climate change, making improvement of the inspection activities of the authorities necessary.

Accreditation

In many countries of Sub-Saharan Africa, official medicines control laboratories are recognized under a national compliance monitoring programme to be compliant with the Principles of Good Laboratory Practice (GLP) of the OECD. This recognition is not to be understood as equivalent to an internationally recognized accreditation.

The effectiveness of this system for the assurance of the technical competence of official medicines control laboratories in the countries of Sub-Saharan Africa and the possibilities to promote the accreditation of these laboratories could be evaluated.

Regulation/Transversal aspects

Besides the aspects already named in terms of medication in times of climate change, criteria for quality assurance should be included in the most relevant technical regulations. For example, technical regulations could require the accreditation of official medicines control laboratories and adequate disposal services. Moreover, in order to increase the effectiveness of quality assurance of medication, the inclusion of the topic in public policies, awareness raising activities and training programmes is required.

A key component is the qualification of laboratory personnel. In this context, the adaptation of curricula to the current quality-related requirements is especially important. New training methods, such as blended learning and the use of medical knowledge databases could help to increase and update knowledge in the sector. Online courses and e-learning programmes, as provided by the AFRAC, bring together knowledge of accreditation, conformity assessments and Mutual Recognition Arrangements in one user-friendly, easily and freely accessible online platform and are aimed at building capacity for accreditation in Africa, thus significantly strengthening human resources and quality infrastructure (AFRAC 2016).

Health reporting, surveillance and monitoring for disease prevention control

As described in subsection 2.6.1, the effects of climate change will increase the burden of disease in Sub-Saharan Africa; in particular, infectious vector-related diseases as well as waterborne infections will spread, but also non-communicable chronic diseases as well as hazard-related injuries will increase. Since poor health will significantly increase, reliable and timely health reporting, surveillance and monitoring systems will be urgently required. The creation of information systems on health conditions is a key element to exchange information on the nationwide and cross-boundary health status, not only with health facilities, but also with medical laboratories and medicine providers in order to prepare and respond to emerging threats. To strengthen the health sector, the collaboration with and among healthcare providers, laboratories and hospitals to obtain information is mandatory. At present, health reporting, surveillance and monitoring systems in Sub-Saharan Africa are inexistent, insufficient or lacking application of common processes resulting in limited data reliability. This is especially due to limited financial and human resources, insufficiently developed tools, methods and guidance (Isere et al. 2015). The largest challenges include insufficient data (time series are too short, too few observations, not frequent enough), wrong, delayed information input, erratic data management, underreporting or mal-reporting, unavailability and dysfunction of software, network and electricity and IT services and the lack of communication.

Metrology

Calibration services mainly need to provide traceability of the clinical testing laboratories involved in the systems, as indicated above (see the section on “Medical laboratory infrastructure”).

Standardization

To ensure the application of unified processes for monitoring the climate change-related spread of diseases (especially vector-related diseases such as malaria and dengue fever and increased waterborne diseases such as diarrhoea and cholera), standards and guidance documents are needed. Additionally, the adaptation or establishment of standardized case management protocols for the most common diseases is needed. The following standards and guidance documents are especially relevant:

- The ISO/TR 14639 guidance document on health informatics and capacity-based eHealth architecture is a roadmap providing best practice guidance on the implementation and use of information and communication technologies. This concept was newly developed to strengthen health information systems which could be applied in Sub-Saharan Africa.
- The WHO (2015a) Operational Framework for building climate resilient health systems suggests integrated risk monitoring and early warning which consider all relevant environmental and meteorological risks, as well as risks regarding water, sanitation and hygiene.

Moreover, in terms of health reporting, surveillance and monitoring, it is important that the national standardization bodies are represented in the relevant international technical committees (in this context, especially ISO/TC 215 Health informatics), ensuring the consideration of specific national and regional aspects in international standardization processes. Additionally, evaluations should be conducted in order to clarify whether guidance documents like ISO/TR 14639 need to be adapted to specific regional or national conditions to facilitate their application.

Testing, certification and inspection

To provide reliable data for national and international health reporting, surveillance and monitoring systems, testing laboratories must to apply quality management systems and should be accredited as explained above (see the section on “Medical laboratory infrastructure”) (Perkins et al. 2017).

Certification and inspection schemes would require specific standards and technical regulations, which currently do not exist in the area. The development of such schemes would likely improve the safeguarding of quality of health-related information in the long-term.

Accreditation

The accreditation of testing laboratories, certification and inspection bodies involved in the creation and quality control of health-related information is increasingly important given the importance of reliable information in times of climate change. The accreditation should be fostered in specific policies and programmes.

Regulation/Transversal aspects

In order to implement national health reporting, surveillance and monitoring systems, national policies in the Sub-Saharan African countries defining the organizations involved and making reference to the quality criteria to be applied (with reference to the international or national guidance documents mentioned above) are needed. Considering the importance of these systems for health protection of the Sub-Saharan African population in times of climate change, responsibilities, organization and processes (with reference to standards and guidance documents) should also be defined in technical regulations and laws.

Links to other thematic areas of this study

Energy: The health sector has large energy demands. Ensuring energy access for health facilities, while reducing their environmental footprint, can both increase climate resilience and reduce global carbon emissions (see Annex 4).

Meteorology: Health is represented in the UNFCCC process; partnerships such as a joint WHO/WMO office on climate information for health are being implemented (WHO and UNFCCC 2015). For accurate surveillance and early warning of disease outbreaks, detailed time series weather data and other meteorological data are needed.

Water: Safe water and adequate sanitation and sewerage infrastructure which is adapted to climate change is a vital precondition for the prevention of diseases and for the protection of human health, (WHO/UNICEF JMP n.d.).

Agriculture: Climate change exacerbates the risks of hunger and malnutrition through extreme weather events and long-term and gradual climate risks, thus severely affecting human health (WFP n.d.). Also pesticide use and the impact on human health need to be considered.

Quality infrastructure services/Value chain	Quality challenges	Metrology	Standardization	
Maintenance/ Monitoring	<ul style="list-style-type: none"> ■ Lacking reliability of clinical analysis and incorrect sampling ■ Lack of adequately trained laboratory personnel 	<ul style="list-style-type: none"> ■ Calibration for most relevant equipment, especially mass, temperature and volume 	<ul style="list-style-type: none"> ■ Adopt existing international standards to the national standard framework, e.g. ISO 15189:2012 and WHO & TDR GLP ■ Inform about standards and promote their application (e.g. via the elaboration of specific national guidance documents) 	
Handling of samples	<ul style="list-style-type: none"> ■ Incorrect handling & damage of samples, inadequate hygiene, breakdown of cooling chain, incorrect disposal of infectious material 			
Installation	<ul style="list-style-type: none"> ■ Installation errors, infrastructure safety, lack of hazard protection 			
Planning	<ul style="list-style-type: none"> ■ Inadequate site selection, exposure to disruption by extreme events, lack of access to safe water and sewerage infrastructure and to electricity and IT services 		<ul style="list-style-type: none"> ■ Definition of specific national guidance documents on planning, considering changed environmental conditions, with reference to international standards ■ Integration of training facilities for laboratory personnel into the laboratory planning processes ■ Risk planning for extreme events 	

Table 14: Quality issues and necessary services of quality infrastructure along the value chain of medical laboratories

Quality infrastructure services/Value chain	Quality challenges	Metrology	Standardization	
Market surveillance	<ul style="list-style-type: none"> ■ Uncertainty about the quality of used components 	<ul style="list-style-type: none"> ■ Equipment calibration, especially in the areas of temperature and humidity 	<ul style="list-style-type: none"> ■ Adopt existing international standards to the national standard framework, e.g. ISO 11238, ISO 11615 and ISO 11239 ■ Development of international/national standards on new drugs (McMichael et al. 2003), representation of Sub-Saharan African standardization bodies in relevant international technical committees to include their specific needs ■ Development of specific international or national standards on transport and storage of medicines under specific environmental conditions 	
Effect	<ul style="list-style-type: none"> ■ Ineffectiveness of medication, unexpected side effects and reactions, adverse reactions 			
Handling	<ul style="list-style-type: none"> ■ Wrong handling of medication, inadequate hygiene standards ■ Insufficient information or foreign languages 			
Storage	<ul style="list-style-type: none"> ■ Lack of climate-proof storing options, lack of cooling options, lack of reliable information and local conditions, lack of adequate hygiene standards, thus degradation of medication 			
Transport	<ul style="list-style-type: none"> ■ Degradation or dissolution of, or damage to medication 			

Table 15: Quality issues and necessary services of quality infrastructure along the value chain of medication

	Testing	Certification	Inspection	Accreditation	Regulation/Transversal aspects
	<ul style="list-style-type: none"> ■ Conduct medical tests according to ISO 15189:2012 and (if possible) with an internationally recognized accreditation, based on accredited calibration services ■ Organization of proficiency tests on national and regional level. 	<ul style="list-style-type: none"> ■ Certification of laboratory material, personnel equipment and reference material ■ Labelling (WHO Laboratory Quality Standards) 	<ul style="list-style-type: none"> ■ Regular laboratory and process inspections to ensure compliance with product quality standards ■ Border inspections of imported pharmaceuticals and reagents 	<ul style="list-style-type: none"> ■ Accreditation of medical testing laboratories and metrological laboratories by internationally recognized accreditation bodies ■ Accreditation of proficiency test providers and reference material producers 	<ul style="list-style-type: none"> ■ Promotion of the accreditation of medicinal laboratories in related policies and programmes
			<ul style="list-style-type: none"> ■ Infrastructure safety inspection Commissioning procedures 		<ul style="list-style-type: none"> ■ Training on handling according to international procedures
	<ul style="list-style-type: none"> ■ Testing of environmental conditions of medical laboratories, if possible by accredited laboratories 		<ul style="list-style-type: none"> ■ Definition of specific inspection schemes of storage facilities and disposal services (hazardous material) 		<ul style="list-style-type: none"> ■ Definition of commissioning procedures, incl. quality criteria and assurance measures ■ Awareness raising on quality aspects. ■ Disaster management

	Testing	Certification	Inspection	Accreditation	Regulation/Transversal aspects
	<ul style="list-style-type: none"> ■ Official medicines control laboratories must provide services for effective market surveillance and ensure reliability of results. 		<ul style="list-style-type: none"> ■ Inspection of manufacturers, importers, exporters, wholesalers, distributors and pharmacies 	<ul style="list-style-type: none"> ■ Evaluation of the effectiveness of the current practice of GLP; recognition and possibilities to promote an internationally recognized accreditation 	
	<ul style="list-style-type: none"> ■ Testing of product quality according to international standards. 				<ul style="list-style-type: none"> ■ Definition of criteria for quality assurance and inclusion into the most relevant technical regulations
					<ul style="list-style-type: none"> ■ Awareness raising on quality aspects
					<ul style="list-style-type: none"> ■ Foster possible network of reference laboratories
					<ul style="list-style-type: none"> ■ E-learning programmes and online courses for medical personnel ■ Adequate disposal services

Quality infrastructure services/ Value chain	Quality challenges	Metrology	Standardization	
Maintenance/Monitoring	<ul style="list-style-type: none"> ■ Insufficient data (time series too short, too few observations, not frequent enough), wrong or delayed information input, erratic data management, underreporting or misreporting, unavailability and dysfunction of software, network and electricity and IT services, lack of communication 	<ul style="list-style-type: none"> ■ Provide calibration and traceability for most relevant equipment 	<ul style="list-style-type: none"> ■ Adopt existing international standards to the national standard framework, e.g. ISO/TR 14639 ■ Adaptation or establishment of standardized case management protocols for the most common diseases needed ■ Inform about standards and promote their application (e.g. via the elaboration of specific national guidance documents) ■ Integrated risk monitoring and early warning which consider all relevant environmental, meteorological and WASH-related risks 	
Implementation	<ul style="list-style-type: none"> ■ Installation errors, wrong and insufficient usage, lack of manpower, lack of communication 		<ul style="list-style-type: none"> ■ Development of new international or national standards for monitoring climate change-related disease, adapt or establish standardised case management protocols for the most common diseases, taking account of national standards and guidelines (Sphere) ■ Representation of national standardization bodies in relevant international technical committees (esp. ISO/TC 215 Health informatics) 	

Table 16: Quality issues and necessary services of quality infrastructure along the value chain of health reporting, surveillance and monitoring for disease prevention control

Definitions

Exposure is the amount of a factor to which a group or individual is subjected, sometimes contrasted with dose (the amount which enters or interacts with the organism). Exposures may be either beneficial or harmful. Exposure to climatic conditions which affect health is heavily influenced by location, socioeconomic conditions and human behaviour.

A health system comprises all the organizations, institutions and resources which are devoted to producing actions principally aimed at improving, maintaining or restoring health. Health systems involve numerous stakeholders from individual and community to government, at local, subnational and national levels. The health system is recognized by the WHO to be made up of six key building blocks: (i) leadership and governance; (ii) health workforce; (iii) health information systems; (iv) essential medical products and technologies; (v) financing; all of which lead to (vi) service delivery. The goal of a health system is to equitably and efficiently deliver effective preventive and curative health services to the whole population while protecting individuals from catastrophic healthcare costs (WHO 2016a).



	Testing	Certification	Inspection	Accreditation	Regulation/Transversal aspects
	<ul style="list-style-type: none"> ■ Establish surveillance laboratory networks according to international procedures and (if possible) with internationally recognized accreditation 	<ul style="list-style-type: none"> ■ Develop certification schemes for reporting and surveillance systems 	<ul style="list-style-type: none"> ■ Develop inspection schemes for reporting and surveillance systems 	<ul style="list-style-type: none"> ■ Accreditation of testing laboratories, certification and inspection bodies 	<ul style="list-style-type: none"> ■ Set-up of policies defining organizations involved with reference to the quality criteria to be applied ■ Legally binding technical and quality requirements for reporting, surveillance and monitoring, including quality assurance mechanisms

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Additional literature of interest

ILAC Brochures:

- ILAC B1:10/2015 Why Use an Accredited Laboratory?
- ILAC B3:10/2015 How Does Using an Accredited Laboratory Benefit Government & Regulators?
- ILAC B4:11/2015 The Advantages of Being An Accredited Laboratory
- ILAC B5:06/2013 Securing testing, measurement or calibration services – The difference between accreditation and certification
- ILAC B6:05/2011 Benefits for Laboratories Participating in Proficiency Testing Programs
- ILAC B7:10/2015 The ILAC Mutual Recognition Arrangement
- ILAC Guidance documents
- ILAC-G26:07/2012 Guidance for the Implementation of a Medical Laboratory Accreditation System

ILAC Accreditation Procedures:

- ILAC P8:12/2012: ILAC Mutual Recognition Arrangement (Arrangement): Supplementary Requirements and Guidelines for the use of Accreditation Symbols and for Claims of Accreditation Status by Accredited Laboratories and Inspection Bodies.
- ILAC P9:06/2014: ILAC Policy for Participating in Proficiency Testing Activities
- ILAC P10:01/2013: ILAC Policy on Traceability of Measurement Results
- ILAC P12:04/2009: Harmonisation of ILAC Work with the Regions
- ILAC P13:10/2010: Application of ISO/IEC 17011 for the Accreditation of Proficiency Testing Providers
- ILAC P14:01/2013: ILAC Policy for Uncertainty in Calibration
- ILAC P15:07/2016: Application of ISO/IEC 17020:2012 for the Accreditation of Inspection Bodies

Part 3 – Analysis of Quality Infrastructure Services Offered in Selected Sub-Saharan African Countries and Potential for Development

On the basis of the identified demand for quality infrastructure services in the selected sectors in times of climate change presented in chapter 2, chapter 3 provides information about the current status of quality infrastructure in four national studies. Insights from desk research and interviews are combined to give an overview of the existing quality infrastructure institutions, existing services and potential for development in Kenya, Ethiopia, Uganda and Benin.

3.1. Kenya

Authors: Niels Ferdinand, Carmen Morales

3.1.1. Main findings from the Kenya country study

A brief overview of the overall level of relevance of key sectors at national level, their priority in terms of climate change and opportunities identified for further development of quality infrastructure in Kenya is presented in the following table.

Recommendations

Based on the results from the national study in Kenya, three main recommendations can be deducted in relation to the overall relevance of analysed key sectors at the national level, their priority in the context of climate change and opportunities for future development of quality infrastructure therein.

1. Climate change adaptation is considered a priority in the political agenda of Kenya and thus the Kenyan government appears to be a relevant and suitable cooperation partner for designing and implementing quality infrastructure-related projects for response to climate change. Up to now, the demand for quality infrastructure services in times of climate change is not being identified and considered systematically by the national quality infrastructure organizations. Fostering the cooperation between the relevant sectors (especially water, agriculture and meteorology and renewable energy) and the quality infrastructure organizations and supporting the development of the needed quality infrastructure services can be seen as an important opportunity in this context.
2. For the time being, agriculture will remain the economic backbone of Kenya. At the same time, the sector is a) affected continuously by climate variability and extremes, and considered to be most severely affected by climate change, while b) the vast majority of the country's greenhouse gases are emitted from this source. At the same time, basic quality infrastructure services needed by the sector are already offered, which could be further expanded and improved. Therefore, putting a focus on quality infrastructure services related to climate change in the agricultural sector appears to be most relevant and promising in the overall development context of Kenya. Close linkages exist however between the agricultural and the water sectors and meteorology, hence it might be worthwhile to evaluate possible joint approaches.
3. Considering the regional scale, meteorological services provided by the Kenya Meteorological Department not only offer meteorological services nationally,

but serve – in cooperation with the World Meteorological Organization (WMO) – global meteorological databases, weather forecasts and climate projections for the whole East African region. Important cooperation opportunities especially exist in the calibration of the equipment used in the Regional Instrument Centre in Kenya and the support of its accreditation. Project activities fostering the cooperation between meteorology and quality infrastructure could result in pilot cases which are also highly interesting for other developing economies.

3.1.2. Kenya's background

Political and economic context of Kenya

President Uhuru Kenyatta has governed Kenya since 2013 with The National Alliance (TNA) party. The Kenyan government's national long-term development plans aim at economic transformation through the "Kenya Vision 2030" which aims at transforming Kenya into a newly industrializing, middle-income state providing high quality

	Relevance at national level	Priority in climate change context	Opportunities for quality infrastructure development
Renewable Energies	<ul style="list-style-type: none"> As part of Kenya's national long-term development plan "Vision 2030", more energy at lower cost is planned to be produced. Renewable energies (geothermal, solar and wind power) will be strengthened. 	<ul style="list-style-type: none"> National Climate Change Action Plan suggests expansion in renewables and clean energy options. Hydroelectricity generation is affected by climate extremes such as droughts. Decreasing hydroelectricity generation can lead to increased greenhouse gas emissions. 	<ul style="list-style-type: none"> At present, there is a low quality infrastructure development status and a low demand for quality infrastructure services. Yet, demand is potentially to increase in the future with higher awareness of importance of quality in the sector.
Energy Efficiency	<ul style="list-style-type: none"> As part of Vision 2030, efficiency in energy consumption is planned to be increased. New regulations exist on energy efficiency in buildings. 	<ul style="list-style-type: none"> Enhancement of energy and resource efficiency (over the long run) is envisaged in National Climate Change Action Plan. 	<ul style="list-style-type: none"> At present, there is low quality infrastructure development status in metrology and testing. Higher demand can be expected with new standards and Kenya Energy Label.
Meteorology	<ul style="list-style-type: none"> As part of the Social Strategy of Vision 2030, rehabilitation of the hydro-meteorological data gathering network is envisaged. National Meteorological Department of Kenya has a hub function for the entire East African region. 	<ul style="list-style-type: none"> Sector is criticized for lacking reliability of forecasts. Quality of meteorological observations is particularly important for near time forecasts and calculation of climate trend prediction. 	<ul style="list-style-type: none"> There are important needs for a) calibration and, possibly, b) accreditation. Unified processes for quality assurance and data sharing are needed.
Agriculture	<ul style="list-style-type: none"> As part of Vision 2030, processing and adding value to agricultural products is aimed at. Need for better soil and land management, resilient seeds, high quality pesticides and fertilizers. 	<ul style="list-style-type: none"> Climate change forecasted to lead to declining production levels. Sector impacted by water scarcity and reduced soil productivity (e.g. erosion). Resilience along agricultural value chain is set as priority in National Adaptation Plan. 	<ul style="list-style-type: none"> Basic quality infrastructure services already offered. Development opportunities in specific standards, testing and metrological services. Agriculture as priority area for the German Ministry for Economic Cooperation and Development (BMZ) in Kenya.
Water	<ul style="list-style-type: none"> As part of the Social Strategy of Vision 2030, improved water and sanitation shall be made available to all. Commercially oriented water service provision is formalized and regulated. 	<ul style="list-style-type: none"> Water scarcity is an important topic in the public perception. Water scarcity combined with reduced water quality and quantity increases water-borne diseases and affects water pricing. 80% of Kenya's land is already today classified as arid and semi-arid. 	<ul style="list-style-type: none"> Need to improve the existing test bench for water meters (could serve as regional reference). Need for accreditation of testing laboratories. Water and sanitation priority area for BMZ in Kenya.
Human Health	<ul style="list-style-type: none"> As part of Vision 2030, an efficient, high quality health care system is planned. 	<ul style="list-style-type: none"> Risk of climate-sensitive (food-, water- and vector-borne) diseases. Existing national health adaptation strategy. Development of malaria early warning system. 	<ul style="list-style-type: none"> At present, relatively low demand for quality infrastructure services. Interest in developing legal metrology and secondary calibration labs. Health as priority area for BMZ in Kenya.
Status of relevance/priority/opportunities		High	Medium
			Low

Table 17: Relevance, priorities and opportunities for quality infrastructure development in relation to climate change in Kenya

life to all its citizens by 2030. The Vision focusses on three key pillars: economic, social and political development (UNDP 2017), and is to be implemented in successive five-year medium-term plans. Flagship projects integrated in the Vision 2030 include different thematic areas which coincide with the focus areas of this study.

Kenya is classified as a lower middle-income country, with an average per capita GDP of USD 1,450. The country's Human Development Index is 0.555, which is slightly higher than the average 0.523 of the total average of Sub-Saharan Africa countries (UNDP 2015). However, Kenya's Corruption Perceptions Index worsened to 26 in 2016, in comparison to 25 in the two previous years of 2015 and 2014 (Transparency International 2017). As expressed in the stakeholder interviews, corruption is still and will remain a central concern in Kenya's political-economic context.

Agriculture represents the backbone of Kenya's economy, contributing to over one-third of the national GDP. About 80% of Kenya's workforce engages in farming or food processing. Kenya produces tea, coffee, maize, cattle, horticulture and sugarcane, among other things. Small-scale, rain-fed farming or livestock production represents the majority of Kenya's agricultural output. Besides agriculture as the most important economic sector, the tourism, services, transport and communication sectors, as well as mining, are important for the country's economy both in terms of revenue generated as well as in the overall workforce engaged.

Evidence of climate change in Kenya

Effects of climate change and relevant hazards

In Kenya there are several sectors which are particularly sensitive to climate change, such as agriculture (mainly rain-fed), energy, tourism, water and health. The country's economy is highly dependent on these sectors and, as a consequence, climate change is a critical issue for the country's development (MENR 2015). Extreme climate events such as droughts and floods occur more frequently. The country's drought cycles have been reduced over time and droughts recorded in the period between 2007 and 2012 were occurring on a yearly basis causing severe crop and livestock losses, famine and population displacement (MENR 2016). Exacerbated drought conditions may have significant impacts on water availability and general well-being (GoK 2016).

Excessive flooding in Kenya occurs relatively frequently. However, the annual rainy seasons are becoming wetter, causing floods and inundations. Health-related impacts as a result of floods range from waterborne to sanitation-related diseases (typhoid, cholera, malaria and diarrhoeal diseases). Floods constantly damage critical infrastructure on which the national economy depends. Poor urban planning and rapid urbanization further aggravate the situation (GoK 2016).

Sea level rise is likely to intensify floods in combination with extreme weather events. Water supply shortages, salinization problems and aquifer contamination as well as inundations in low-lying areas are risks caused by sea level rise. The agricultural sector along the coast also tends to be impacted with harvesting losses (GoK 2016).

Impacts of climate change on different areas

Energy: Hydroelectricity generation, the main source of electricity in Kenya, is affected by extreme events such as droughts. Decreasing hydroelectricity generation could lead to higher prices and greater use of fossil fuels, which increases greenhouse gas emission.

Agriculture: Roughly 70% of rural livelihoods in Kenya are dependent on rain-fed agriculture. This sector is mainly impacted by unpredictable rainfall, reduced soil productivity through erosion and increased evapotranspiration leading to a decline in agricultural production. Maize yields are predicted to increase in mixed rain-fed temperature and tropical highlands; arid and semi-arid areas will experience significant declines in crop yields.

Environment, Water and Forestry: Climate change in Kenya severely affects natural ecosystems. This leads to environmental degradation along with negative social and economic consequences for the Kenyan population. Arid and semi-arid areas for example, are particularly vulnerable ecosystems due to their dry conditions with emerging risks such as land degradation and desertification. Increasing water scarcity leads to declining forest coverage, reduced water quality and quantity for domestic use and industrial use, high water pricing and increases in waterborne diseases. Forests at risk can lose their natural ecosystem services such as soil erosion reduction, natural pest control and conservation of water availability and water quality maintenance. Greenhouse gas emissions are also increased by deforestation and forest degradation.

Human Health: Kenya's population is at a high risk for climate-sensitive infectious diseases such as food- or water-borne diseases like diarrhoea, hepatitis A and typhoid fever. Vector-borne diseases such as malaria, dengue fever and Rift Valley Fever are prevalent as well. High temperatures and intense rainfall are known to be critical factors for the initiation of malaria epidemics in Kenya (MENR 2016).

Institutional and policy framework for climate change mitigation and adaptation

In Kenya, institutional arrangements and policies for the response to climate change are widely in place. The legal framework comprises the Climate Change Act of 2016 and the Energy Act of 2006. Additionally, climate change-specific policies are framed by other policies, including the National Environment Policy and the National Policy for Disaster Management.

The Climate Change Act is very specific in terms of institutional arrangements for climate change coordination. A National Climate Change Secretariat was established under the Ministry of Environment and Natural Resources through the Climate Change Act (MENR 2016).

The Energy Act from 2006 encompasses several energy-related laws. The Act mandates the government to promote the development and use of renewable energy.

Additionally, the National Environment Policy 2013 aims to provide a framework for an integrated approach to sustainable management of Kenya's environment and natural resources. At the same time, the National Policy for Disaster Management (2009) aims at institutionalizing mechanisms to address climate change-related disasters and associated vulnerabilities (LSE 2017).

Overall, climate change is a priority on Kenya's political agenda. However, like in other countries in Sub-Saharan Africa, the implementation and enforcement of climate change policies has potential for improvements.

Climate change and national quality infrastructure institutions in Kenya lack cooperation in some areas such as accreditation in the environmental (including agriculture and water) sector. As will be mentioned in section 3.1.4 under accreditation, the Ministry of Environment and Natural Resources does not "recognize" Kenya Accreditation Service (KENAS) as an accreditation body for testing

laboratories conducting tests for its regulations. KENAS, on the other hand, is interested in developing new services related to climate change.

Climate change mitigation

Kenya's total greenhouse gas emissions amounted to 73 MtCO₂eq in 2010, which is relatively low in the global context. In Kenya, a large proportion of the population depends on charcoal as its main household fuel. The demand for agricultural land and urban expansion is increasing, which adds further strains to forest resources. Roughly 75% of greenhouse gas emissions in Kenya originate from land use, land use change and, more specifically, forestry and agricultural sectors. Energy and transport sectors, as well as waste processing and industrial processes are other important sources of emissions, even though to a lesser extent (MENR 2015).

Energy regulations on solar water heating, energy management and solar photovoltaic systems were passed in 2012 (Kenya Meteorological Department 2017). The Intended Nationally Determined Contributions (INDC) in Kenya make note of mitigation contributions towards the 2015 Climate Agreement in Paris. Kenya seeks to reduce greenhouse gas emissions by 30% by 2030 by pursuing a low carbon, climate-resilient development pathway. Although the enforcement of these regulations is lacking to a large extent, their existence establishes a direction into a climate-compatible development pathway and sets the stage for improved climate change mitigation.

Based on the National Climate Change Action Plan (NCAP, 2013–2017), Kenya seeks to promote and implement the following mitigation activities: expansion in renewable energy (geothermal, solar and wind) and clean energy options, enhancement of energy and resource efficiency, tree covering, reduction of reliance on wood fuels, low-carbon and efficient transportation systems, climate smart agriculture and sustainable waste management systems (MENR 2015).

In the context of this study, climate change mitigation actions and policies are considered to be particularly relevant for the energy and the agricultural sectors:

- **Renewable energies & energy efficiency:** Expansion of renewable energies (geothermal, solar and wind energy), clean energy options and enhancement of energy and resource efficiency are integrated in the National

Climate Change Action Plan. Development of Nationally Appropriate Mitigation Actions (NAMAs) proposals to attract investment for biogas, solar lighting, geothermal and waste initiatives is currently under way.

- **Agriculture:** 75% of the greenhouse gas emissions in Kenya originate from land use, land use change and, more specifically, from the forestry and agricultural sectors. Reduction of greenhouse gas emissions can be achieved, for example, through agroforestry or conservation tillage. Both approaches form a central part of climate smart agriculture.

Climate change adaptation

Given a comparatively low level of greenhouse gas emissions, especially when compared to western industrialized countries, Kenya places more emphasis on the adaptation to the effects of climate change than on mitigation. Kenya aims at ensuring enhanced resilience to climate change by 2030 through mainstreaming climate change adaptation into the medium-term plans of Vision 2030 and implementing adaptation actions.

Adaptation actions presented in the National Adaptation Plan are related to several sectors, including health, environment, water and irrigation, population, urbanization and housing, tourism, agriculture, livestock development and fisheries (MENR 2015). The implementation of the National Adaptation Plan is likely to enhance long-term resilience and adaptive capacity, particularly related to droughts, floods and sea level rise. With drought being considered the main hazard, the National Drought Management Authority is a key institution in enhancing adaptive capacity (GoK 2016).

In the context of this study, climate change adaptation actions and policies are particularly relevant for the agriculture, water and health sectors:

- **Agriculture:** The overall adaptation action integrated in the National Adaptation Plan aims at enhancing the resilience of the agricultural value chains. The promotion of sustainable climate smart agriculture methods is instrumental for making the sector more resilient to the impacts of climate change. Some medium-term actions include promotion of drought-tolerant value crops, water harvesting for crop production or integrated soil fertility management.
- **Water:** The National Adaptation Plan also aims at mainstreaming climate change adaptation in the water sector. Some medium-term actions in the water sector include the strengthening of water resource monitoring and assessments for early warning and planning, as well as the promotion of technologies which enhance water resource efficiency.
- **Human health:** In the health sector, climate change is to be mainstreamed in relevant areas of the health system. A medium-term priority will be to design appropriate measures for surveillance and monitoring of climate change-related diseases in order to enhance early warning systems (MENR 2016).

Multilateral and bilateral cooperation activities

In the context of multilateral and bilateral cooperation in Kenya, activities are manifold in all sectors covered by the study presented here. In the following, initiatives and programmes implemented by multilateral and bilateral cooperation are briefly described. Given its overall economic and social importance, development partners are particularly engaged in the agricultural sector, including climate change-related projects. However, no cooperation activities are currently being implemented in the area of quality infrastructure.

Multilateral cooperation

United Nations Development Programme (UNDP): One among the four main programmes of the UNDP in Kenya is called “Environmental Sustainability, Renewable Energy and Land Management”. Two focus areas in this programme are climate change adaptation and mitigation and sustainable energy access. Additionally, chemical management is another topic in which UNDP is engaged in Kenya, supported by the Global Environmental Facility (GEF). At community level, UNDP engages in rehabilitation of natural springs and drilling of boreholes for water management (UNDP 2017).

World Bank Group (WBG): Among WBG initiatives relevant in the context of this study is the “Kenya Climate Smart Agriculture Project” which was launched in 2017. Investments are also made in other areas including agribusiness, transport, energy, water and urban development, followed by the social sectors including human health. Improvement of agrometeorological forecasting and monitoring, as well as strengthening climate-smart

agricultural research and seed systems are other topics in which WBG is engaged (World Bank 2017).

Bilateral cooperation

German Federal Ministry for Economic Cooperation and Development (BMZ): The German bilateral engagement, mainly financed by the BMZ, comprises the following priority areas: agriculture (focusing on food security and drought resilience), the development of the water and sanitation sector and support for the health sector (BMZ 2017).

German Society for International Cooperation (GIZ): The agricultural sector receives approximately 25 % of the GIZ funding volume in Kenya. GIZ activities in the agricultural sector focus on innovation to increase employment, food security and drought resilience. On behalf of BMZ, GIZ is working with local and international partners to improve access to safe water, health care services and renewable energies development. One project directly related to quality infrastructure was implemented in Kenya between 2009 and 2013 by GIZ. The initiative called “African Eco-labelling Mechanism” developed African Eco-Labeling Standards (AES) in the agriculture, fisheries, forestry and tourism sectors. While the objective of these initiatives was to improve the access of African products to international markets, African economies were also supported in adapting to climate change and contributing to greenhouse gas mitigation (GIZ 2017).

German Development Bank (KfW): KfW supports Kenya in a) improving water supply and sanitation systems, b) bringing forward productive agricultural development and c) introducing a widespread healthcare system. In the energy sector, KfW puts a focus on the construction of geothermal power plants and rehabilitation of hydropower stations (KfW 2017).

3.1.3. Analysis of thematic focus areas

Renewable energies and energy efficiency

With an average economic growth rate of 4.7 % between 2004 and 2017, Kenya depends on generating more energy at a lower cost while at the same time increasing efficiency in energy consumption. Therefore, Kenya’s government is committed to institutional reforms including a strong regulatory framework, encouraging private power

generators and separating power generation from distribution.

For the time being though, the topic of energy efficiency is of no crucial importance for the Kenyan government; rather, the priority is the question of how to provide more (and more stable) energy to an ever-growing population and industry.

Traditionally, Kenya has had a strong focus on hydropower production for sustaining the domestic energy market. With ever-increasing demands for energy, the further development of new energy sources such as geothermal energy is considered important. Yet, geothermal exploration remains expensive and resource-consuming.

There is a need to collect more reliable data for advancements in the development of new energy sources, in order to keep exploration costs at a calculable level. Hence, new sources of energy in focus are renewable energies such as geothermal power, but coal continues to play a role.

All in all, solar energy does not (yet) play a predominating role in the Kenyan energy sector and in the political agenda, even though potential for further development is considered high. Further advancement of rural electrification programmes is planned, based on the installation of solar electricity generators for 74 public institutions and an energy access scale-up programme (Kenya Vision 2030).

Among national institutions, the National Commission for Science, Technology and Innovation (NACOSTI) plays an important role in planning for the successful enhancement of renewable energies in the long run: NACOSTI regulates and ensure quality in the science, technology and innovation sector and advises the Government in matters related thereto. Physical science, chemistry, meteorology and geology are some of the topics covered by the Commission. However, NACOSTI has not yet sufficiently considered the relevance of quality infrastructure in their work.

Meteorology

As in other countries, meteorology is considered to be an important interdisciplinary area in Kenya which plays a central role for the provision of a sound data basis related to weather forecasting and climate change. Under the Kenya Vision 2030, some aspects of the meteorological infrastructure and services are planned to be restructured

and modernized, including the rehabilitation and further development of the hydro-meteorological data-gathering network.

Institutions relevant for meteorology in Kenya are the Kenya Meteorological Department, as a national institution, and – related to the agricultural sector – the International Centre of Insect Physiology and Ecology (ICIPE), as an international research organization.

The Kenya Meteorological Department – which belongs to the Ministry of Environment and National Resources – serves as the national and regional hub for the provision of meteorological and climatological services to agriculture, forestry, water resources management, civil aviation and the private sector. With its mandate to maintain an efficient telecommunications system for rapid collection and dissemination of meteorological information, the department has strong ties with the World Meteorological Organization (WMO) and its regional training centre (WMO-RTC), same as with the International Civil Aviation Organization (ICAO) whose procedures it aims to follow. The Kenya Meteorological Department publishes meteorological information on national level and also provides regional data for Eastern Africa to the WMO Information System.

Currently, the Meteorological Department works on the national implementation of the WMO Integrated Global Serving System, thereby fostering the sharing of meteorological data between all relevant national ministries and institutions (e.g. the ministries of agriculture and fishery). The department runs a data quality centre for analysing national as well as regional meteorological data based on models which are also used by the UK Meteorological Office (UKMET). The models applied are based on WMO Guidelines and serve the entire East African region, but according to interview partners, neighbouring national meteorological departments still use different quality monitoring models, which prevents the region from using and applying a uniform approach.

In the frame of these prevailing conditions, the International Centre of Insect Physiology and Ecology (ICIPE) aims to contribute to alleviating poverty, to ensure food security and to improve the overall health status of people living in the tropics by following an interesting both national and regional approach: Through the “Climate Change Impacts on Ecosystem Services and Food

Security in Eastern Africa (CHIESA)” project, automatic weather stations have recently been installed in different locations in Kenya, Tanzania and Ethiopia in order to assess the microclimate variability with respective national meteorological headquarters. One of the outcomes of the project was an increased capacity of the African research communities to access, collect, develop, use and manage scientific information in climate change-related matters. Against this background, it becomes clear that a) an approach for collaborating with the Kenyan Meteorological Department should not only consider the national, but importantly also the regional (Eastern African) scale, in which b) opportunities for collaborating with a meteorological institution such as DWD for supporting further development of meteorological services both in Kenya and in the region may be analysed.

While focusing on the meteorological sector, the “holy trinity” in which the agricultural and the water sector also play an important role should not be dismissed. Following a systemic approach for the whole of the three sectors might mean to be closest to meet the demands of an agriculture-dependent nation such as Kenya and its neighbouring countries.

Agriculture

Agriculture is by far the most important economic sector of Kenya, both in terms of revenue generated and the overall workforce involved. All in all, the sustainable economic development of Kenya will depend on progress to be made in economic revenues earned in agriculture in both domestic and international markets.

Based on the Kenya Vision 2030, interventions are planned in the agricultural sector following the objective of generating higher yields and adding value to farming products before they reach the market. Differences between pre-production, production and post-production levels are not yet made in the overall development strategies.

Yet, Kenya’s strategy for the agricultural sector includes preparation of new land for cultivation by developing more irrigable areas in arid and semi-arid areas (which can be titled as proper governance at pre-production levels), and by improving market access for small holders through better marketing (post-production levels). At production scale, in which quality infrastructure services play a predominantly important role, conditions are not yet sufficiently considered.

Altogether, the Kenyan agricultural growth strategy is more growth- than quality-oriented. Exemplary and relevant initiatives in the agricultural sector which are currently envisaged are, for example, a Fertilizer Cost-Reduction Initiative as well as Development Projects in arid and semi-arid land areas (Kenya Vision 2030).

Stabilizing production conditions as well as guaranteeing sufficient amounts and a steady supply of agricultural products for the domestic market is not only important for the agricultural sector, but for the overall national economy of Kenya. Soaring prices of agricultural products due to prolonged drought conditions in some parts of Kenya pushed inflation above 9% in March 2017.

Against this background, a wide range of national institutions, research institutes and international cooperation organizations are active in improving overall conditions in the agricultural sector. Among those, the International Plant & Nutrition Institute (IPNI), the Eastern Africa Grain Council (EAGC) and the World Agroforestry Centre (ICRAF) take centre stage.

As a science-based organization, the International Plant & Nutrition Institute (IPNI) covers topics of soil and crop response, fertilizers and organic resources. Climate change is a reference topic for this organization. Researchers engaged in this institution in Kenya are currently working on the crop-specific application of fertilizers. They cooperate with different laboratories such as the International Centre for Research and Agroforestry (ICRAF) or nationally recognized laboratories like the Crop Nutrition Laboratory Services (CROPNUTS).

The Eastern Africa Grain Council (EAGC) mainly supports structured grain trade in the Eastern and Southern Africa region. Being active in policy advocacy, EAGC facilitates an efficient, profitable and inclusive grain trade. The organization is active in 10 Sub-Saharan African countries, covering the trade of several grain species like maize, rice, sugar, millet etc. Members of the council are private sector actors including producers, service providers, insurance providers etc.

The World Agroforestry Centre (ICRAF) is an international centre of scientific excellence possessing the world's largest repository of agroforestry science and information. Due to its significance in testing services, further information on the centre can be found in section 3.1.4. under

"Testing". The organization is especially innovative and active in the Kenyan context.

Water

In the water sector, Kenya aims at conserving water sources and at ensuring that improved water and sanitation are available and accessible to the whole population. Increased access to safe water and sanitation in both rural and urban areas and the promotion of agricultural productivity through irrigation are priorities at the national level. Within the water and environment sector, activities such as rehabilitation of hydro-meteorological stations, development of multi-purpose water conservation structures and dams, the rehabilitation of irrigation schemes, the implementation of sewage initiatives and the mapping of land coverage and land use are planned (Kenya Vision 2030).

During the implementation of the national study, more detailed insights into the water sector were provided by the Kenyan Institute of Environment and Water Management (IEWM) and the private company David & Shirliff. While IEWM aims at strengthening water and environmental governance and increasing climate change resilience through advocacy, research training and capacity building in Kenya, David & Shirliff aims at providing water and energy solutions in a regional context. By focusing on six principal product sectors (water pumps, boreholes, swimming pools, water treatment, generators and solar equipment), the company is the leading supplier of water-related equipment in the East African region. It was found that resolving prevailing challenges in the water sector, also in terms of quality infrastructure-related aspects including reliable and correct water metering, might comprise the involvement of both public and private institutions. Overall, an enhanced and trustworthy water metering is expected to lead to improved water management and less water shortages.

Human Health

Regarding the human health sector, according to the Kenya Vision 2030, the country aims at providing an efficient and high-quality health care system for its growing population. This includes a) devolving funds and management of health care to the communities and to district medical officers; and b) shifting the bias of the national health bill from curative to preventive care. Specific strategies involve the provision of a robust health infrastructure network and the improvement of the quality of health ser-

vice delivery. Revitalization and integration of community health centres promoting preventive health care is another priority (Kenya Vision 2030).

Over the course of the national study, a more detailed understanding of prevailing challenges for the health sector in Kenya could be achieved.

On the one hand, the Ministry of Health in Kenya is composed of different departments like the Department of Standards and Quality Assurance and Regulations, under which several quality infrastructure topics are covered. Health inspections of medical centres are primarily organized by the Ministry of Health internally, although capacities are limited. At the same time, the Ministry of Health is ISO 9001 certified while health centres are still lacking certification. Recently, the Ministry of Health in cooperation with several development partners have developed a Quality Model for Health and a training course in order to guide health managers in strengthening quality management at all levels. However, the impact of the implementation of this model has not been evaluated yet.

On the other hand, the WHO in Kenya follows a number of strategic priorities in the country which are potentially related with quality infrastructure topics covering the human health thematic area: For example, strategic priority 5 follows the objective to strengthen existing capacities for disaster preparedness, surveillance and effective response to disease outbreaks, acute public health emergencies and the effective management of health-related aspects of humanitarian disasters (WHO 2017). Therefore, there are several topics where possible links between the Ministry of Health, PTB and WHO could be defined.

3.1.4. Quality infrastructure services in relevant areas

Quality policy, regulation and important institutions

Quality infrastructure in Kenya is organized in a centralized manner, with the most relevant functions covered by the Kenya Bureau of Standards (KEBS). KEBS serves as the national standardization organization, national metrology institute and legal metrology authority. KEBS also runs the national Technical Barriers to Trade (TBT) entry point. Additionally, it acts as an inspection and certification body as well as a testing laboratory and training institute in different areas, especially those related to Kenyan Standards and quality signs emitted by KEBS. The functions and government structure of KEBS are regulated in the Standards Act 2012 (Laws of Kenya 2012). A national quality policy does not exist.

KEBS’ organizational structure comprises the following divisions:

- Standards Development and International Trade Division
- Quality Assurance Division
- Testing and Metrology Services Division
- Finance and Administration Division

The National Standards Council is the policy-making body for supervising and controlling the administration and financial management of the Bureau. The Managing Director of KEBS is responsible for the administration of the organization. The organization has around 1,200 employees, including its regional offices. KEBS is nationally

Quality infrastructure status	Metrology	Standardization	Testing	Certification and inspection	Accreditation
Renewable energy					
Energy efficiency					
Meteorology					
Agriculture					
Water					
Human health					

Quality infrastructure development status	High	Medium	Low	No information
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Table 18: Development status of quality infrastructure in relevant sectors

recognized as the central actor of quality infrastructure, especially in the area of standardization.

Metrology

The KEBS metrology department is one of the most advanced national metrology institutes in the region. A broad range of metrological services is offered, covering the areas included in the table below.

The functions of KEBS in the area of metrology are regulated in the Weights and Measurement Act of 2012 (National Council for Law Reporting 2012).

The metrology department is a member of AFRIMETS (AFRIMETS 2017). It became a full member of the General Conference of Weights and Measures (CGPM) of the Metre Convention and a signatory of the Committee of Weights and Measures Mutual Recognition Arrangement (CIPM-MRA) in 2010 (KEBS 2017a). The tables below summarize the intercomparisons registered under BIPM,

Calibration and Measurement Capabilities (CMC) presented and the German Accreditation Institute (DAkkS) accreditations held by KEBS.

In the thematic areas considered in this study, especially the following metrological services of KEBS are of special interest:

Renewable energy and energy efficiency

For renewable energies and energy efficiency, especially the metrological services in the areas of direct current and low frequency measurements, energy and transformers as well as photometry are of interest. Also in these areas, relatively few national metrology institutes in the region offer calibration services and especially access to an AC/DC laboratory with an internationally recognized accreditation is advantageous for the industry. In the other areas mentioned, the accreditation or presentation of CMCs may be seen as an opportunity for further development.

Mechanical Metrology Laboratories	Electrical Metrology Laboratories
Mass Pressure Temperature Density and viscosity Force Volume and Flow Dimensional metrology	Time and frequency AC/DC (direct current and low frequency measurements) Energy and transformer Photometry Acoustics and vibration Dosimetry (ionizing radiation) Mechanical workshop and instrumentation

Table 19: Metrological services offered by KEBS

Registered intercomparisons under BIPM with KEBS participation	CMCs presented by KEBS
Ionizing radiation (for Kenya traceability to the BIPM in the field of dosimetry is established through BIPM calibrations made for the International Atomic Energy Agency - IAEA) Mass Time (BIPM 2017)	Acoustics, ultrasound and vibration Chemistry for food (ethanol in aqueous media and cadmium in brown rice)

Table 20: Registered intercomparisons and CMCs presented

Electrical quantities	Temperature quantities	Mechanical quantities
<ul style="list-style-type: none"> ■ DC voltage ■ AC voltage ■ DC current ■ DC resistance 	<ul style="list-style-type: none"> ■ Resistance thermometers ■ Liquid-in-glass thermometers 	<ul style="list-style-type: none"> ■ Mass (mass standards) ■ Volume of flowing liquids ■ Force

Table 21: KEBS: Metrological quantities accredited by DAkkS (DAkkS 2017)

Furthermore, important metrological services for the renewable energy and meteorology sectors are missing, for example in the areas of wind speed, humidity and solar irradiance (calibration of pyranometers).

Meteorology

KEBS offers several metrological services which could be of interest for the meteorology sector, including the Meteorological Department and the climate stations in the country. These services, among others, are offered in the areas of temperature, volume and pressure as well as time and frequency. Not all of these services are accredited, which could be seen as an area for improvement. Also, several services important for the sector are missing, including the ones mentioned above for renewable energy and energy efficiency, as well as for humidity, for example.

Agriculture

In the area of agriculture, basic metrological services such as mass and temperature are offered. However, important services for the agricultural sector are missing at present, e.g. moisture and humidity. As described in section 2.4 on agriculture, the provision of traceability in these areas will be of increasing importance in times of climate change.

Water

For the water sector, especially the area of flow is of interest, as only few national metrology institutes in Sub-Saharan Africa offer services in this area. As part of a PTB project, a test bench for water meters was installed. It can be used for the calibration of flow meters of up to 250 mm. The national water providers do not have the required equipment to calibrate macro water meters. For this reason, the calibration of micro as well as macro meters is a service frequently offered by KEBS.

Human health

The demand for calibrations in the health sector has been relatively low in the past. As the demand for these services, especially by hospitals, rises, KEBS is now planning to expand its services in this area. KEBS envisages supporting hospitals in enhancing their internal calibration laboratories, e.g. in the areas of temperature, mass, conductivity and pressure.

Secondary metrology laboratories

Secondary calibration laboratories offer a broad range of services. A total of 14 secondary calibration laboratories are accredited by KENAS, covering among other things

the areas of mass, pressure, temperature, weighing scales, water and power meter calibration, force, time, torque and volume (KENAS 2017a).

An important secondary calibration laboratory in the scope of this study is the laboratory of the Meteorological Department in Nairobi. The laboratory serves as a Regional Instrument Centre (RIC) of the World Meteorology Organization (WMO). This means that it serves as a calibration laboratory not only for the national weather stations, but also for Tanzania, Uganda, Ruanda, Burundi, Ethiopia, Djibouti, Sudan and Eritrea. The laboratory offers calibration of the most important equipment used in weather stations (for temperature, humidity, rainfall, pressure and radiation) but not for wind speed.

Contacts between KEBS and the Meteorological Department on the calibration of the equipment of the calibration laboratory were initiated, but were not met with interest. For this reason and as no further calibration services are used (e.g. via WMO) at present none of the equipment of the laboratory is calibrated. Intercomparisons (e.g. with other meteorological calibration laboratories) are not done frequently and not for all of the methods applied.²⁵ The calibration of the equipment and the realization of intercomparisons seem to be important areas for a potential cooperation with the organizations of quality infrastructure (e.g. KEBS), especially considering its role as Regional Instrument Centre.

At present, the laboratory is not accredited. Training and consultancy to support the implementation of ISO 17025 and posterior accreditation could be seen as another important area for cooperation with the quality infrastructure institutions.

Legal Metrology

The Department of Weights & Measures of the Ministry of Industry, Trade and Cooperatives is responsible for legal metrology in Kenya. The legal basis of the department is defined in two Acts of Parliament, namely the Weights and Measures Act, Cap. 513, and the Trade Descriptions Act, Cap. 505 (State Department of Trade 2017). The department is a member of the OIML (OIML 2017). Its services are available throughout the country through 21

²⁵ According to its latest update report from May 2017, the RIC Kenya participated in intercomparison measurements for pyranometers and resistance thermometers. Additional information will be available on the website of WMO shortly.

“Zonal Offices” (State Department of Trade 2017). The organization has 100 inspectors in total.

In the thematic areas considered in this study, the following information on the current status of legal metrology in Kenya is of special interest:

Renewable energy and energy efficiency

At present, the verification of electricity meters is only based on document checks. The Legal Metrology Department is in the procurement process of a test bench for electricity meters.

Meteorology

No specific legal metrology services are offered in the meteorology sector.

Agriculture

In the area of agriculture, regulations for fertilizers and pesticides exist, but the implementation is not being inspected. According to the information received, this is mainly due to the lacking resources of the authorities.

Water

For water meters, a certificate in country of origin is required. The certificates are checked by the Legal Metrology Department. For new models, a process of pattern approval and initial verification is required. The measurements required are conducted by KEBS. In this context, it must be considered that the flow laboratory of KEBS is not accredited, so that the results of a pattern approval could be mistrusted, for example in a lawsuit. Inspectors may check whether the requirements are fulfilled, but due to capacity restrictions very few inspections are realized.

Human health

At present, the legal metrology capacities in the health sector are rather limited and only include pressure and temperature. Also in this sector, no inspections are being conducted by the Legal Metrology Department.

Standardization

KEBS is Kenya's standardization body under the Ministry of Industry, Trade and Cooperatives. KEBS is a member of the International Organization for Standardization (ISO) (with participation in a relatively high number of Technical Committees [TCs]) (ISO 2017) and a member of the ARSO (ARSO 2017).

In March 2009, Kenya launched a new requirement for imports. In addition to the pre-shipment verification of conformity, imported products must also obtain an import standards mark (ISM) issued by KEBS. Fake ISMs were found on the packaging of counterfeit products entering Kenya already before the ISM was legally required (Privacy Shield Framework 2017).

In the thematic areas considered in this study, the current stage of standardization may be summarized as follows:

In the *renewable energy* sector, it was mentioned that specific standards for technologies such as photovoltaic and solar water heating would be needed.

In the area of *energy efficiency*, KEBS has recently adopted 10 energy performance standards and test procedures, developed with the support of the United Nations Industrial Development Organization (UNIDO) between Tanzania, Uganda, Rwanda and Burundi. The following products are covered: electric motors, air conditioners, compact fluorescent lamps, fluorescent lamps, fluorescent ballasts and refrigerators. In Kenya, these products will be marked with the Kenya Energy label (UNDP 2017). In this context, it must be considered that at present there are no energy efficiency laboratories in Kenya (the section on “Testing” see below).

In the area of *meteorology*, at present there are no specific Kenyan standards, as processes and methods are mainly defined in WMO internal guidelines.

In the *agricultural* sector, many standards exist for general agricultural processes and specific commodities. KEBS/Kenya took over the Food and Agriculture Organization/World Health Organization (FAO/WHO) Codex Coordinating Committee for Africa from 2016 for 2 years (FAO 2016).

In the *water* sector, several standards define the criteria for equipment and processes needed for drinking water and waste water management.

In the *human health* sector, several interview partners mentioned that criteria for products with potential health impacts are defined in Kenyan Standards, but that more specific standards on processes and management systems in public health institutions would be needed.

Currently, standards and technical regulations are not being clearly differentiated in Kenya. In this context, KEBS is defined as “regulatory body (...) mandated to develop and ensure compliance with (...) product standards” (Export 2017). All Kenyan product standards become legally binding after being gazetted, with KEBS being the only certification body allowed to certify based on these standards. This practice is not compliant with international requirements and good practices. It results in unnecessary barriers to trade and ineffective quality control mechanisms.

These policy and organizational issues can be seen as more relevant than the existence or lack of all standards relevant for the thematic areas considered in this study. The most important areas in this context seem to be covered in the Kenyan standard system, including for example standards on greenhouse gases and solar water heaters. According to KEBS, there is a need to standardize climate resilient varieties in the agricultural sector, to define standards for water and carbon foot printing and to create a validation scheme for CO₂-emissions. Stakeholders of the agricultural sector confirm the need for new standards for varieties as well as on the composition and origin of seeds. Some stakeholders mentioned that the lacking implementation of standards is an important issue. For example, grains used in food and beverage production are only tested every four months by KEBS.

Testing

At present, 17 testing laboratories and 21 clinical laboratories in Kenya are accredited by KENAS (KENAS 2017b). The areas covered include microbiology, chemicals, agriculture, water, food safety, human health and drugs. At present, there is no laboratory association or network to support the collaboration between testing laboratories.

In the thematic areas considered in this study, the following information on the current status of the testing capacities in Kenya is of special interest:

In the *renewable energy* sector, there are very limited capacities in important services required for an effective quality control, for example testing of photovoltaic modules. The area of energy efficiency is currently not covered by any testing laboratories. This leads to the situation that compliance of products with the energy performance standards (see the “Standardization” section above) and the Kenya Energy label may not be tested in the country.

In the *agricultural* sector, there are only few soil laboratories, as the demand for soil testing at present is limited. Some tests required by the sector are not offered in Kenya, so that producers have to send their samples to other countries.

Only three accredited laboratories offer water tests. None of the public institutions are accredited. This can be seen as an important gap, as they are the main laboratories involved in the monitoring of drinking and waste water.

In the *human health* sector, there are accredited laboratories both in public and private organizations, including individual laboratories as well as internal laboratories in hospitals and research organizations.

In the following, two laboratories which are especially interesting in the context of the study are described more in detail.

KEBS Testing Department

The KEBS Testing Department offers its services in the areas of chemistry, food, microbiology, material engineering and textiles. The testing services are offered to both internal and external customers. Product tests are carried out against national standards, international standards, specific government and other client specifications (KEBS 2017b). According to information provided by KEBS, the laboratories comply with ISO 17025. However, at present none of the laboratories are accredited.

In the thematic areas considered in this study, the following information on the current status of the KEBS testing laboratories is of special interest:

The gas laboratory conducts tests of industrial and vehicle emissions, including CO₂. The equipment is calibrated with reference gases purchased in South Africa. Based on these reference gases, the laboratory also provides calibration services for other laboratories in Kenya.

The electrical laboratory at present has basic equipment for testing energy electrical quantities. Based on this equipment, also the current of photovoltaic modules is being tested. At present, no further tests relevant for energy efficiency or renewable energies can be provided, but it is planned to expand the testing services in these areas in the future.

World Agroforestry Centre (ICRAF)

The World Agroforestry Centre (ICRAF) is a scientific centre generating science-based knowledge about the roles which trees play in agricultural landscapes. The centre receives its funding from many different partners including governments, private foundations, international organizations, regional development banks and the private sector.

The testing laboratory of ICRAF is part of the Africa Soil Information Service (AfSIS) and of the Global Soil Spectroscopy Network. As such, it serves as a hub for the creation and exchange of information on the characteristics of soils in Africa, which is used, for example, for the elaboration of digital maps on soil quality.

Together with a German provider of laboratory equipment, ICRAF has developed innovative dry testing methods for soils using mobile devices (such as an alpha near infrared spectrometer for soil characteristic analysis and an X-ray spectrometer). These devices make the testing of soil parameters in the field possible, increasing efficiency substantially. Besides soil, the X-ray spectrometer can also be used for plant and fertilizer analysis, for example. Carbon and nitrogen in soil and plant samples are analysed with a gas chromatograph.

The laboratory uses National Institute of Standards and Technology (NIST) reference material to calibrate most of its equipment, e.g. plant leaves, reference gases and soil samples. In this context, it was stated that specific reference material for Africa with high element values is lacking.

The laboratory is not accredited, as the accreditation is seen as too costly and not flexible enough to adapt to new procedures developed as part of ICRAF's research activities.

Certification and inspection

KEBS acts as a certification body for products, systems and personnel. The certifications are realized based on Kenyan as well as international standards. In the thematic areas considered in this study, the following certification services of KEBS are of special interest:

- ISO 14001 Environmental Management Systems
- HACCP Food Safety Management Systems
- ISO 22000 Food Safety Management Systems
- ISO 50001 Energy Management Systems
- ISO 13485 Medical Devices
- Personnel certification compliant with ISO 17024 (KENAS 2017c)

As of September 2005, KEBS implemented the Pre-Export Verification of Conformity programme (PVoC) to ensure that regulated products imported into the country comply with the applicable Kenyan Standards and/or Technical Regulations. SGS is the only company authorized to provide the service worldwide and has been operating the PVoC programme in Kenya for the last seven years. All consignments of regulated products need to obtain a Certificate of Conformity (CoC) issued by SGS prior to shipment of the goods. The CoC is a mandatory document for customs clearance in Kenya. Any cargo arriving to destination without the CoC will be denied admission into the country (SGS Group 2012). The KEBS Certification Body is accredited by the Dutch Accreditation Council (KEBS 2017c). Other relevant private certification bodies include the following: SGS Kenya, Bureau Veritas and InterTek Services.

Relevant inspection bodies in Kenya include the following:

- **KEBS:** Among other things, inspection of goods at Port of Entry.
- **Kenya Plant Health Inspectorate Service (KEPHIS):** Inspection of all imported plant materials.
- **Pest Control Products Board (PCPB):** Registration of all agricultural chemicals imported to or distributed in Kenya based on test results. It also inspects and licenses all premises involved in the production, distribution and sale of the chemicals.
- **Kenya's Pharmacy and Poisons Board (PPB) and the Ministry of Health:** Inspection and registration of all pharmaceutical drugs manufactured or imported into the country (Export 2017).
- Private inspection bodies, for example SGS Kenya.

Six private and no public inspection bodies in Kenya are accredited by KENAS (KENAS 2017d). Especially the public inspection bodies do not have sufficient trained staff to effectively ensure compliance with quality and safety criteria in their area of competence.

There are plans to build up an inspection scheme for green buildings, which would be relevant for the thematic area of energy efficiency. Other interview partners indicated that there are plans to develop specific inspection schemes for hydropower and geothermal power plants.

Accreditation

KENAS is the national accreditation body. It is an organization with its own budget under the Ministry of Industry, Trade and Cooperatives. It is a member of the International Accreditation Forum (IAF) and an associate member at the International Laboratory Accreditation Cooperation (ILAC). The organization has 37 staff members (a relatively high number) and 60 assessors. Authorities finance approximately 75% of the organization, while 20% of the funding is generated through training activities and 5% is provided by external partners (e.g. PTB or the EU).

Currently, KENAS is in the international recognition process. Last year, the organization was peer-evaluated by AFRAC and ILAC in the areas of testing laboratories, medical laboratories, certification and inspection bodies. Currently, the observations are being implemented; the Mutual Recognition Agreement (MRA) could be signed earliest this year.

KENAS offers accreditation services in the following areas:

- a. Certification bodies
 - Management Systems ISO/IEC 17021
 - Personnel ISO/IEC 17024
 - Products, processes and services ISO/IEC 17065
- b. Testing and calibration laboratories ISO/IEC 17025
- c. Medical laboratories ISO 15189
- d. Inspection and verification bodies ISO/IEC 17020
- e. Proficiency test providers ISO/IEC 17043
- f. Reference medical laboratories ISO/IEC 15195
- g. Veterinary laboratories ISO/ IEC 17025 & OIE

A challenge for KENAS is its lacking recognition by some authorities in Kenya and the missing inclusion of quality criteria for conformity assessment in the relevant technical regulations. For example, the Ministry of Environment and Natural Resources has an own system to “recognize” testing laboratories which may conduct tests according to its regulations, without making reference to an accreditation by KENAS. Another example is clinical laboratories which do not have to be accredited according to the relevant technical regulations.

KENAS sees new services related to climate change as an important strategic area for its future development. Among other things, the organization plans to offer accreditation of certification bodies for energy management systems and of organizations offering CO₂ emission verification.

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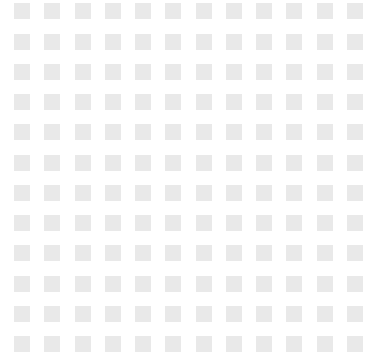
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3.2. Ethiopia

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3.2.1. Main findings from the Ethiopia country study

A brief overview of the overall level of the relevance of key sectors at the national level, their priority in terms of climate change and opportunities identified for further development of quality infrastructure in Ethiopia is presented in the following table.

Recommendations

The following main recommendations can be made based on the results from the Ethiopia country study, taking into consideration the overall relevance of analysed key sectors at the national level, their priority in the context of climate change and opportunities for future development of quality infrastructure.

1. A number of strategies for climate resilient development have been launched between 2011 and 2015 by different Ethiopian ministries indicating commitment of the Ethiopian government, especially in the agriculture, water and energy sectors. These sectors are particularly relevant, due to their high exposure to risks in times of climate change. Quality assurance and related services have not been systematically taken into consideration in these strategies. Raising awareness about possible benefits and thus supporting the collaboration between ministries, quality infrastructure organizations and private sector actors could foster a more efficient and effective implementation of climate change adaptation and mitigation efforts.
2. For the agriculture and water sectors, a number of relevant quality infrastructure services already exist. An ongoing PTB project is to further strengthen quality infrastructure for innovations related to agriculture. It could be an opportunity to expand the scope of a possible follow-up project to support quality infrastructure services with relevance for climate change adaptation efforts for the agriculture and water sectors. Clear linkages between the two sectors exist. Cooperation efforts could also support specific services

for the meteorological sector, given the importance of reliable climate data for the other sectors and the expressed interest in expanding services for this sector on the side of the Ethiopian national metrology institute. An example of strong collaboration between metrology and meteorology could foster similar developments in other countries in the region.

3. Climate change-related projects in Ethiopia are mainly carried out by multilateral cooperation partners, like UNDP and World Bank, with quality topics being addressed only marginally. German development partners in Ethiopia are particularly engaged in the education, agriculture and natural resource management sectors. There is no clear focus on climate change yet. Nevertheless, due to the existing national priorities and new climate change-related strategies, a potential cooperation with Ethiopia with this focus can be seen as an opportunity. Supporting the development or improvement of relevant quality infrastructure services could also complement efforts of other German development partners in the areas of drought resilience or renewable energies, for instance.

3.2.2. Ethiopia's background

Political and economic context of Ethiopia

Ethiopia is located in the Horn of Africa and has a population of more than 99 million people. It is the second-most populous country in Sub-Saharan Africa with a population growth rate of 2.5 % in 2015. At the same time, it is also one of the world's poorest countries. The overarching goal of the government's Growth and Transformation Plan (GTP II, 2015/16 to 2019/20) is to turn Ethiopia into a lower-middle-income country by 2025. In order to achieve this, Ethiopia is especially committed to ensuring growth through enhancing the productivity of agriculture and manufacturing, improving the quality of production and stimulating competition in the economy (World Bank 2017, FDRE 2016).

With an average per capita GDP of USD 706, Ethiopia is classified as a low-income country. The country's Human Development Index is 0.448, which is lower than the average 0.523 of the total of Sub-Saharan African countries (UNDP 2015). Furthermore, Ethiopia's Corruption Perception Index scored at 34 in 2016. Over two-thirds of the

	Relevance at national level	Priority in climate change context	Opportunities for quality infrastructure development				
Renewable Energies	<ul style="list-style-type: none"> The Climate Resilient Green Economy strategy includes exploitation of hydro-power. Energy potentials of the country are prioritized in order of importance as follows: hydroelectric power, geothermal energy, wind and solar power. 	<ul style="list-style-type: none"> Due to the energy mix in Ethiopia, the country's vulnerability to climate change is high. Dependence of Ethiopia's hydropower sector on rainfall is emphasized in national climate resilience strategies. Expansion of renewable energies is integrated into the Intended Nationally Determined Contributions (INDC). The Water and Energy Climate Resilience Strategy was launched in 2015. 	<ul style="list-style-type: none"> Currently low development status and low demand for services of quality infrastructure. The importance of services is well understood by representatives of quality infrastructure and increase in demand expected. 				
Energy Efficiency	<ul style="list-style-type: none"> The Climate Resilient Green Economy strategy mentions energy efficiency topics aiming at energy efficiency investments in the electric power generation sector. 	<ul style="list-style-type: none"> Switch to modern and energy efficient technologies in transport, industry and building sectors integrated in Ethiopia's Intended Nationally Determined Contributions (INDC). 	<ul style="list-style-type: none"> At present, low-quality infrastructure development. Higher demand is expected due to increasing interest in the topic. 				
Meteorology	<ul style="list-style-type: none"> In Ethiopia's second Growth and Transformation Plan, the meteorological contribution emphasizes on agro-, hydro- and bio-meteorological forecasting and early warning. Meteorology sector is closely inter-linked with other sectors. 	<ul style="list-style-type: none"> The Water and Energy Climate Resilience Strategy entails data systems development for decision-support (rainfall, temperature data). The Agriculture and Forestry Climate Resilience Strategy includes activities such as capacity building and institutional coordination for climate information. 	<ul style="list-style-type: none"> Some services in metrology available. National metrology institute expressed interest to expand its services in the area. 				
Agriculture	<ul style="list-style-type: none"> The agricultural sector development plan follows an acceleration and sustained growth of agriculture within the framework of the Climate Resilient Green Economy strategy. 	<ul style="list-style-type: none"> The agricultural sector is particularly sensitive to climate change in Ethiopia. 51% of the greenhouse gas emissions in Ethiopia originate from agriculture related activities including livestock. The Agriculture and Forestry Climate Resilience Strategy was launched in 2015. 	<ul style="list-style-type: none"> Basic quality infrastructure services are available. Development opportunities in specific metrological and testing services. 				
Water	<ul style="list-style-type: none"> Activities in the second Growth and Transformation Plan include water supply, irrigation and drainage development, hydropower studies, surface and groundwater studies. 	<ul style="list-style-type: none"> Demand for water is likely to rise and impacts of climate change may act as an additional stressor, affecting the quantity and quality of water resources. The Water and Energy Climate Resilience Strategy was launched in 2015. 	<ul style="list-style-type: none"> Some basic services exist, but important gaps remain. Need for accreditation of testing laboratories. 				
Human Health	<ul style="list-style-type: none"> The actual Growth and Transformation Plan primarily aims at providing equitable, accessible and quality primary health service. The focus lies in implementing primary health care at all levels of the health delivery system 	<ul style="list-style-type: none"> Health impacts of climate change will be felt through an increase in vector-borne and non-vector borne diseases as well as injury and mortality through floods and storms, etc. Existing national health adaptation strategy. 	<ul style="list-style-type: none"> Basic quality infrastructure services are offered. Some potential for improvement and expansion of specific services. 				
<table> <tr> <th>Status of relevance/ priority/ opportunities</th><th>High</th><th>Medium</th><th>Low</th></tr> </table>				Status of relevance/ priority/ opportunities	High	Medium	Low
Status of relevance/ priority/ opportunities	High	Medium	Low				

Table 22: Relevance, priorities and opportunities for quality infrastructure development in relation to climate change in Ethiopia

176 countries in the world in 2016 fall below the midpoint of the scale of 0 (highly corrupt) to 100 (very clean). Based on this index, Ethiopia is perceived as less corrupt than its neighbours, including Kenya and Uganda (Transparency International 2017, World Bank 2017).

As one of the fastest growing non-oil producing economies in Africa, Ethiopia has sustained a high annual growth since 2004. Currently, 80 % of the country's employment comes from the agricultural sector. However, other areas such as industry are increasingly gaining importance (UNDP 2017).

Evidence of climate change in Ethiopia

Effects of climate change and relevant hazards

Average temperatures in Ethiopia have increased over the past century and human induced climate change will bring even further warming, which is likely to be associated with heat waves and higher evapotranspiration. Regarding the future distribution, timing and intensity of rainfall there is much uncertainty. Moreover, a higher regularity in heavy rainfall events is expected, which is likely to result in increased flooding. Altogether, the most vulnerable sectors to climate change include health, agriculture, water, energy, buildings and transport (crgevision 2011, FDRE 2015). Impacts of climate change on different areas

Energy: Even though the vast majority of Ethiopia's national energy needs are met with fuel wood, crop and animal waste human and animal power, 95% of electricity generated in Ethiopia comes from hydropower. Furthermore, the hydropower sector is yet to be fully developed within the country. Due to this energy mix, the country's vulnerability to climate change is very high. The reliance on fuel wood and charcoal brings widespread land degradation and a major exposure of soil to erosion. At the same time, energy generated by hydropower is vulnerable to fluctuations in rainfall, temperature and evaporation.

Agriculture: The agricultural sector is a very climate-dependent sector and therefore particularly vulnerable to the future impacts of climate change. As a consequence, developing climate resilience is especially crucial for the agricultural sector in Ethiopia. Climate change impacts on the sector include increases in soil erosion and higher incidences of crop damage. Furthermore, socioeconomic phenomena such as demographic pressures and degradation of land area worsen the already critical situation.

Changes in pest and disease frequency, in cropping patterns and drought and flood damages are other impacts which may affect the agricultural sector (crgevision 2011).

Water: Ethiopia has relatively abundant water resources and to date, only a small proportion has been developed for sectors such as hydropower, agriculture and water supply and sanitation. Nevertheless, demand for water is likely to rise as these sectors develop. Impacts of climate change may act as an additional stressor, affecting the quantity and quality of water resources, especially in low rainfall areas such as the lowlands (USAID 2012).

Human health: The health impacts of climate change will be felt through different climate-relevant health outcomes such as higher mortality rates through extremes temperatures, increases in vector-borne (e.g. malaria) and non-vector borne diseases (diarrhoeal diseases and cholera associated with floods and droughts) as well as injury and mortality through floods and storms etc. Already today, 68 % of Ethiopians live in malaria risk areas (crgevision 2011).

Institutional and policy framework for climate change adaptation and mitigation

Since Ethiopia ratified the UNFCCC in 1994, some efforts have been made on climate-related issues in the country. The late Prime Minister, Meles Zenawi, initiated efforts to fight climate change in Africa and to generate green growth in the country and in the region. In 2011 the government finalized its Climate Resilient Green Economy strategy for integrating measures of economic performance with those of environmental performance, such as improving resilience to climate shocks, mitigation of greenhouse gas emissions and biodiversity loss and ensuring access to clean water and energy. In August 2015, two reports which present climate resilience strategies for the agriculture and forestry and the water, irrigation and energy sectors in Ethiopia were launched by the Ministry of Environment and Forest (MEF), the Ministry of Agriculture (MoA) and the Ministry of Water, Irrigation and Energy (MoWIE).

Even though there is no legal framework in place, institutional arrangements and policies for responding to climate change are given in Ethiopia (LSE 2017, GGGI 2017).

Climate change mitigation

Ethiopia's total greenhouse gas emissions amounted to

150 MtCO₂eq in 2010. About 42 % of greenhouse gases were emitted by livestock, 9 % by crop cultivation and 37 % by deforestation and forest degradation. The electric power generation, transport, industrial and building sectors emitted the remaining 12%. Just as in other countries in Sub-Saharan Africa and considering Ethiopia being the second-most populous country in Sub-Saharan Africa, its emissions are very low. The Intended Nationally Determined Contributions (INDC) in Ethiopia intend to limit its net greenhouse gas emissions in 2030 to 145 MtCO₂eq or lower. Through the implementation of the Climate Resilient Green Economy strategy, a resilient economic development pathway in the country and a decrease in greenhouse gas emissions is likely to be achieved (FDRE 2015).

The Ethiopian National Energy Policy (updated in 2012) was developed in order to comprehend new energy development-related issues and to give emphasis to the development and utilization of all renewable energy sources. The existence of this policy sets the ground for improved climate change mitigation (Ministry of Water and Energy 2013).

Just as in Kenya, in the context of this study, climate change mitigation actions and policies are considered to be particularly relevant for the energy and the agricultural (including livestock) sectors.

- **Renewable energies and energy efficiency:** The expansion of renewable energies and the switch to modern and energy efficient technologies in transport, industry and building sectors are activities integrated in Ethiopia's Intended Nationally Determined Contributions (INDC). Additionally, the Ethiopian Energy Authority (EEA) and the Green Economy strategy aim at implementing some energy efficiency strategies of interest for this study such as a national energy efficiency labelling programme and energy audits in the industrial, commercial and public sectors.
- **Agriculture:** 51 % of the greenhouse gas emissions in Ethiopia originate from agriculture-related activities including livestock. Reduction of greenhouse gas emissions can be achieved, for example, through intensification of agriculture supported by the use of improved inputs and better residue management, development of irrigation infrastructure and the introduction of lower emission agricultural techniques (FDRE 2015).

Climate change adaptation

Ethiopia intends to undertake adaptation initiatives to reduce the vulnerability of its population to the adverse effects of climate change through the implementation of the Climate Resilient Green Economy strategy. The strategy mentions the sectors of the economy most vulnerable to climate change as being agriculture, health, water and energy, buildings and transportation. The Ministry of Water Resources and the Meteorological Service finalized Ethiopia's first Climate Change National Adaptation Programme of Action (NAPA) in 2007. Later in 2010, the NAPA was updated and replaced by the Ethiopian Programme of Adaptation to Climate Change (EPACC) (FDRE 2015, LSE 2017).

In the context of this study, climate change adaptation actions and policies are particularly relevant for the energy, agriculture and water sectors, for which climate resilience strategies were launched in 2015:

- **Renewable energies:** Within the Water and Energy Climate Resilience Strategy, the dependence of Ethiopia's hydropower sector on rainfall is stressed. Due to the potential of hydropower generation shortfalls, the diversification of the energy mix is planned to be reinforced in order to spread the risk.
- **Agriculture:** The Agriculture and Forestry Climate Resilience Strategy in Ethiopia includes adaptation options which touch upon the topics covered in this study (see section 2.4 on agriculture). Some examples of actions included in the strategy are (i) capacity building and institutional coordination for climate information; (ii) information and awareness on meteorological data and agrometeorological data; (iii) crop and water management on-farm through fertilizer and chemical use against pests and diseases and (iv) sustainable agriculture and land management through conservation agriculture, soil management or agroforestry.
- **Water:** The Water and Energy Climate Resilience Strategy covers different water-related areas such as (i) irrigated agriculture, (ii) access to water, sanitation and hygiene and (iii) crosscutting responses. The balance of water demands in order to manage and allocate according to the water which is available is one of the actions to be undertaken; this activity is closely related to quality infrastructure services such as reliable mea-

surement of water consumption and demand (see section 2.5 on water). In the crosscutting area, activities such as data systems for decision-support including rainfall, temperature, river flows, groundwater availability and recharge data represent a strategic priority (GGGI 2017).

Multilateral and bilateral cooperation activities

German development partners in Ethiopia are particularly engaged in the education, agriculture and natural resource management sectors. They do not focus on climate change projects yet. Altogether, climate change-related projects are mainly being implemented by the multilateral cooperation (UNDP and the World Bank).

Multilateral cooperation

United Nations Development Programme (UNDP): UNDP's key interventions in Ethiopia fall under three programme pillars: growth and poverty reduction, climate change and environmental vulnerability as well as governance (UNDP 2017).

World Bank Group (WBG): the World Bank's work in Ethiopia focusses on two principal pillars. On the one hand, they aim to support Ethiopia in achieving a stable macroeconomic environment through increasing agricultural productivity and marketing. On the other hand, the World Bank wants to support the social dimension which includes enhancing the resilience of vulnerable households to food insecurity and resilience to climate change, among other aspects (World Bank 2017).

Bilateral cooperation

German Federal Ministry for Economic Cooperation and Development (BMZ): The German bilateral engagement in Ethiopia, mainly financed by the BMZ, does not focus on climate change related-projects. Agriculture and food security are emphasized as important issues; energy topics are not a priority. Since 2014, development cooperation between Ethiopia and Germany has focussed on the following areas: education, food security and agriculture, and environmental policy, protection and conservation of natural resources and biodiversity (BMZ 2017).

German Society for International Cooperation (GIZ): In line with the Ethiopian Government's objectives, German development cooperation currently focusses on two priority areas: labour-market-oriented education and training and sustainable land management. In addition, a further priority

area for conserving biodiversity was agreed upon at the Ethiopian-German government negotiations in 2014. The agricultural sector actually receives approximately 30 % of GIZ funding volume in Ethiopia. Quality infrastructure is addressed in several projects of GIZ in Ethiopia:

- “Establishing Binding Nationwide Standards for Measurement and the Quality of Industrial Products” focusses on standardization for sustainable infrastructure;
- “Promotion of wild coffee and honey as sustainable forest products” fosters the development of product certification processes and business relationships, while promoting value addition and quality improvements;
- “Contributing to sustainable agricultural productivity” includes the establishment of a quality system for producing seeds and certifying varieties to support rural development. (GIZ 2017).

German Development Bank (KfW): the German Development Bank supports Ethiopia in the following three sectors: education, biodiversity and food security and agriculture (sustainable land management and drought resilience) (KfW 2017).

3.2.3. Analysis of thematic focus areas

Renewable energies and energy efficiency

In Ethiopia, traditional energy sources (such as fuel wood, crop/animal waste and human/animal power) represent the principal sources of energy due to the majority of its population living in rural areas. Only 5 % of energy supply comes from electricity, the majority of which is generated with hydropower. Energy potentials of the country are prioritized in order of importance as follows: hydroelectric power, geothermal energy, wind and solar power. Ethiopia aspires to become a regional power exporter and green energy hub for Eastern Africa. In the Climate Resilient Green Economy strategy finalized by the government in 2011, some energy supply initiatives to build a green economy were highlighted. The exploitation of hydropower and advanced rural cooking technologies were some of the proposed initiatives. The strategy foresees an increase of up to 25GW in generation potential by 2030. Hydropower would contribute 22GW, geothermal energy 1GW and wind energy 2GW.

All in all, solar energy does not play a predominate role in the Ethiopian energy sector and in the political agenda, even though further decentralized off-grid solar energy supply will be promoted under the second Growth and Transformation Plan (GTP II). Through the update and expansion of power transmission and distribution lines, power supply interruption problems in the country might be addressed.

For the time being, hydropower generation is of crucial importance for the Ethiopian government. However, in times of climate change, to rely only on hydropower might pose a risk. Thus, a diversification of power sources should be considered and promoted in energy-related policies and strategies.

The Climate Resilient Green Economy strategy also mentions energy efficiency topics aiming at energy efficiency investments in the electric power generation sector to reduce domestic demand by 30 % by 2030.

All in all, the government recognizes the importance of pursuing energy efficiency while at the same time promoting the expansion of renewable energy (FDRE 2016, LSE 2017).

Meteorology

In Ethiopia's second Growth and Transformation Plan, meteorology development is located under the "Potable Water Supply and Irrigation Development" section. The overall objective of this sector is to achieve the supply of reliable and sustainable meteorological data to the general public, especially to mitigate natural and man-made hazards. At the same time, other meteorological objectives include the provision of world standard weather prediction and early warning services as well as the enhancement of local production of imported meteorological instruments. Ensuring synergies with relevant stakeholders and agencies is also of great importance in this context.

With regard to meteorological contribution to socio-economic development, the plan emphasizes agro-meteorological (for agriculture), hydro-meteorological (for water and energy) and bio-meteorological (for health and disease) forecasting and early warning (FDRE 2016).

Just as in Kenya and other countries, meteorology is seen as a crosscutting area and is closely interrelated with all the sectors covered in this study.

Water

As mentioned above, one of the main strategic directions in Ethiopia's current Growth and Transformation Plan is "Potable Water Supply and Irrigation Development". The plan emphasizes different fundamental water services which are especially relevant for this study as quality infrastructure services are needed. Some of the main priorities within the plan include access to safe and sustainable water supply as well as the assessment of the quantity and quality of the country's water resources. For the latter, quality infrastructure services are especially important. The improvement of wastewater disposal and urban sewerage systems analysed in section 2.5 on water, are focus topics as well. Furthermore, especially relevant considering climate change, are the mitigation of floods and runoff impacts initiatives. Development interventions related to water resources planned within the period of the second Growth and Transformation Plan include water supply, irrigation and drainage development, hydropower studies, surface and groundwater studies and watershed management (FDRE 2016).

Although Ethiopia is not short of water, the water resources are not distributed evenly and therefore the country faces many challenges in providing safe water for all. In order to approach these challenges, Ethiopia's One WASH National Programme was launched in 2016. It was created by the government of Ethiopia in response to the challenges of improving water, sanitation and hygiene throughout the country (OpenWASH 2016).

Agriculture

The agricultural sector constitutes the main pillar of Ethiopia's economy and plays a central role in the life and livelihood of most Ethiopians. About 12 million smallholder farming households account for an estimated 95 % of agricultural production. Furthermore, exports are almost exclusively agricultural commodities, with coffee being the most relevant industry and providing the primary source of income for many thousands of small farmers (FAO 2017).

The second Growth and Transformation Plan addresses challenges related to the supply of agricultural inputs and the utilization of agricultural technologies (pre-production and production phase). Additional input demand will result from the envisaged expansion of agricultural investment outside of smallholder agriculture. As a consequence, input supply is likely to be a major constraint for Ethiopia's agricultural sector. Therefore fertilizer, seeds and agro-mechanization input supplies are planned to be strengthened. The development of smallholder crop and pastoral agriculture will be further enhanced (production phase). As in the first Growth and Transformation Plan, natural resources conservation and management will be carried out to increase agricultural production and productivity. Some of the initiatives include the use of rain-water and water harvesting in moisture-rich areas, small scale irrigation development and soil and water conservation work in moisture stressed areas (FDRE 2016).

Altogether, Ethiopia's agricultural strategy is very growth-oriented. The agricultural sector development plan pursues, first of all, accelerated and sustained growth of agriculture within the framework of the Climate Resilient Green Economy strategy.

Human Health

In Ethiopia, about 80 % of diseases are attributable to preventable conditions which are related to personal and environmental hygiene, infectious diseases and malnutrition (WHO 2013). In order to face human health-related challenges, Ethiopia, in its second Growth and Transformation Plan, primarily aims at providing equitable, accessible and quality primary health service through the health extension programme. The focus is given to implement primary health care at all levels of the health delivery system. Furthermore, strategies to prevent the prevalence of diseases resulting from climate change will be designed. At the same time, the proportion of households with access to improved latrines and open defecation-free facilities will be increased in order to improve access to hygiene and environmental health (FDRE 2016).

Ethiopia faces a number of challenges, which are potentially related to quality infrastructure topics covering the human health thematic area. In regards to (i) medical laboratory infrastructure, the new master strategic plan for laboratory services is being implemented. The Ethiopian Health and Nutrition Research Institute (EHNRI) is putting in place a regional laboratory network in Eastern

Africa. Unfortunately, its efforts are being hampered by issues such as inadequate human resources, limited laboratory supply chain management and poor maintenance of laboratory and other medical equipment.

In the sub-sector (ii) medication, the improvement in the availability and access to essential medicines in the health system is being promoted. The efforts made are partially attributable to the Pharmaceuticals Fund and Supply Agency (PFSA). The Food, Medicine and Health Care Services Administration and Control Agency, has developed a number of guidance documents and model legislation and provided support to other countries in the Eastern African region (WHO 2013).

3.2.4. Quality infrastructure services in relevant areas

Quality policy, regulation and important institutions

In 1987, Ethiopia created the Quality and Standards Authority, an institution responsible for the governance of the country's quality infrastructure. In 1998, it was re-established under Proclamation No. 102/1998 and further amended in 2004. Finally, in 2011, the organization was split into four independent bodies responsible for the country's metrology, standardization, conformity assessment and accreditation services (Mesfin 2011).

Each of these quality institutions is defined in a regulation by the Council of Ministers:

- Council of Ministers Regulation to provide for the establishment of the national metrology institute No. 194/2010
- Council of Ministers Regulation to provide for the establishment of the Ethiopian Standards Agency No. 193/2010
- Council of Ministers Regulation to provide for the establishment of the Ethiopian Conformity Assessment Enterprise No. 196/2010
- Council of Ministers Regulation to provide for the establishment of the Ethiopian National Accreditation Office No. 195/2010 and re-established with regulation No. 279/2012 to be in line with international best practice (Yohannes 2011, Interview 1).

Quality infra-structure status	Metrology	Standardization	Testing	Inspection and Certification	Accreditation
Renewable energy					
Energy efficiency					
Meteorology					
Agriculture					
Water					
Human health					
Quality infrastructure development status	High	Medium	Low	No information	

Table 23: Development of quality infrastructure in relevant sectors

A National Quality Infrastructure Strategy, based on which a policy is planned to be developed, exists (Interview 1).

Metrology

Since 2011, the National Metrology Institute of Ethiopia (NMIE) incorporates the country's legal and industrial metrology structures (NMIE 2017a). Regulation No. 194/2010 declares that the government is responsible for the institution's financing. The government further appoints a General Director, a General Deputy Director and other necessary staff (Federal Democratic Republic of Ethiopia 2010).

The institute is responsible for the establishment and strengthening of the national measurement system. It offers calibration, training and consultancy services on metrology and scientific equipment (NMIE 2017b). Moreover, it gives technical support and provides measurement traceability to legal metrology (Interview 3).

The NMIE maintains the Ethiopian national measurement standards in electricity, mass, length and temperature, and has a secondary standard dosimetry laboratory (NMIE 2017c). Furthermore, the institute offers calibration services with an internationally recognized accreditation by DAkkS in several, but not all of its scopes of services:

- **Mechanical quantities:** mass, weighing instruments, pressure
- **Electrical quantities:** DC voltage, DC current, DC resistance, AC voltage, AC current
- **Chemical analysis, reference materials:** volume of liquids
- **Thermodynamic/temperature quantities:** resistance thermometers, thermocouples, liquid-in glass thermometers, direct reading thermometers, mechanical thermometers (DAkkS 2015).

Additional services in those quantities as well as in length, force, volume, density and ionization and radiation are available, but are still to be accredited (NMIE 2017 c).

In the thematic areas considered in this study, the following metrological services are of particular interest:

Renewable energy and energy efficiency

The NMIE provides accredited services for AC/DC low frequency measurements and has a wide range of calibration services for electrical equipment, including energy meters, ohmmeters and insulation testers, among others. These services are important for the development of renewable energy and energy efficiency. However, important services are still missing; photometry, for determining the energy efficiency of light bulbs for example, calibration services for pyranometers to ensure accurate solar irradiance data and traceability for water flow are crucial to support climate change mitigation efforts.

Meteorology

Services in the area of meteorology include calibration of mercury barometers, climatic thermometers and rain gauge survey meters. An extension of services in the areas of climatic humidity, air velocity (speed measurements) and air quality including carbon emission measurements in chemical metrology are planned (Interview 3).

Agriculture

Existing metrological services for mass, temperature and moisture are important for the agricultural sector. Additional measurements, such as humidity, which gain importance considering the effects of climate change, could be developed to strengthen the sector.

Water

For water, accredited services for volume of liquids and additional services for hydrometers and pressure measurement in hydraulic applications are available. Currently, no services for water flow measurements are offered by the NMIE. The establishment of traceability in this area is very relevant in the context of climate change, as accurate information about water flow is a basis for drinking water distribution, water for agricultural use and hydropower development. It was also mentioned that an extension of services to cater for wastewater quality analysis is needed.

Human health

Accredited metrology services for temperature, mass and pressure exist and are important for the health sector of the country. They will be increasingly important in times of climate change. The services for micro-volumes (e.g. pipettes) and density measuring instruments could be further improved to better fulfil the demand of the sector. An additional service line of the NMIE is the maintenance of scientific equipment, related training and consultancy. Institutions which use scientific instruments are supported during the establishment of their own maintenance workshops and receive training and consultancy by the NMIE which also issues certificates for trainees. Services are available for national institutions like hospitals, research institutes, higher education, quality assurance laboratories and scientific service rendering organizations and include maintenance of the following equipment:

- **Medical equipment:** electrosurgical unit, defibrillator, ECG/EKG, anaesthesia machine, fetal monitor
- **Nuclear and imaging equipment:** X-ray, CT-scan, ultrasound

- **Electro-mechanical equipment:** centrifuge, autoclave, incubator, water bath, washing machine
- **Measurement and analysis equipment:** spectrophotometer, chemistry analyser, moisture tester, digital balance
- **Scientific and medical equipment:** medical or scientific equipment installation, commissioning and maintenance (NMIE 2017d).

The NMIE collaborates with other African countries in the Intra-Africa Metrology System (AFRIMETS) (AFRIMETS 2017). It is not yet a member of international associations like the BIPM (BIPM 2017) or the International Organization for Legal Metrology (OIML) (OIML 2017).

Secondary calibration laboratory

The Quality Management Centre-Calibration and Testing Laboratory Institute of the Metals and Engineering Corporation offers electrical and pressure calibration services, which were accredited by the Ethiopia National Accreditation Office (ENAO) in 2016 (ENAO 2016).

Standardization

The Ethiopian Standards Agency (ESA) was established in 2010 as a non-profit government body under the Ministry of Science and Technology. Currently, it employs 136 fix staff members. ESA's tasks include the development and sales of Ethiopian standards. Furthermore, it provides information, training and technical support on standard implementation and creates public awareness about the importance of standards (ISO 2017). Standardization work in Ethiopia is focussed on the following governmental priority sectors: construction and civil engineering, electro-mechanics, food and agriculture, environment (including health and safety), textile and leather, chemical standards, basic and general standards (Interview 2).

ESA's Standards Council controls national standard development and policy-making activities. It consists of members which have been appointed by the government and which come from various organizations (ISO 2017). Jointly with the Technical Committees, which consist of experts from relevant sectors like industry, government institutions, academia, standard users, professional associations, public sector and regulatory bodies, the Standards Council develops Ethiopian standards (ESA 2017). There are currently 101 Technical Committees and over 10,000 standards have been developed to date (Interview 2).

Industrial actors are increasingly interested in participating in the standard development processes and demand for specific standards from the industries is increasing. In some cases, industry actors gather funding to enable ESA to work on the necessary standards when the yearly government budget is already allocated without the topic of interest being included (Interview 2).

With regards to the thematic areas considered in this study, the following information is of interest:

- Standards for *energy efficiency* and *renewable energy* are developed as part of the electro-mechanical priority area defined by the government, as well as under the category of environment, health and safety. Several ISO standards for refrigeration technology have been adopted. For renewable energies, next to hydropower also wind and solar energy are of interest. Standards for hydraulic and solar energy engineering are available (ESA 2015).
- For *agricultural* production and food, several Technical Committees work on specific topics (e.g. fruit and vegetables, fertilizers, seeds, etc.) (ESA 2015). In 2016, a strong focus was put on standards for seed quality and agricultural machinery (ESA 2016).
- *Water* is also considered under the focus area food and agriculture and a specialized Technical Committee is responsible for standards related to water quality (Interview 2). In 2016, a standard for hydrometry for water level measuring devices was approved. Next to the water sector, this is also of interest for hydropower development, as the determination of water levels is crucial in the planning phase of hydropower installations (ESA 2016).
- *Health* is covered by four Technical Committees which address medical devices for transfusion, infusion and injection, commercialized essential drugs, medical care practices and medical equipment and supplies. Relevant standards are available for medical health care facilities, equipment and medicine (ESA 2015, 2016).

Challenges lie in the implementation of standards. However, as standard development is increasingly demand driven, the subsequent implementation of standards is also increasing. Additionally, the need for preliminary re-

search to gain knowledge before standards are developed and for continued research after the publication to monitor the standards' effectiveness have both been identified. A restructuring of the standardization process is planned in order to allow for preliminary as well as follow-up research (Interview 2).

ESA participates in several international organizations relevant for standard setting. It is a full member of the ISO, where it acts as participating member in 15 and as observing member in 50 Technical Committees (ISO 2017). Moreover, memberships of ESA include the International Electro-Technical Commission (IEC), the Codex Alimentarius Commission (CAC) and the ARSO (ESA 2017b). ESA further collaborates with a number of national standardization bodies around the world, including Korea, Turkey, Germany and Austria and cooperates with the Economic and Monetary Union of the European Union (EMU). In the region, Ethiopia collaborates and exchanges information with Kenya (Interview 2).

Testing

The Ethiopian Conformity Assessment Enterprise (ECAE) is the official conformity assessment body of Ethiopia. It is supervised by the Ministry of Science and Technology. It was established as a public enterprise with an authorized capital of 543 million Ethiopian birr (approx. EUR 19.7 mio.) (Mesfin 2011). The ECAE is equipped with six specialized testing laboratories performing activities in the fields of chemical products, electrical products, mechanical products, microbiology, radiation, textiles and leather (ECAE 2017a). The chemical, mechanical, microbiology, textiles and leather laboratories were accredited by ENAO and their accreditation is due to be renewed. The electrical testing laboratory was accredited in 2016 (ENAO 2017c); the radiation laboratory is in the process of being accredited (ECAE 2017d).

Apart from ECAE, other testing laboratories also offer services in various areas and the number of testing services provided is increasing. From 2011/2012 to 2013/2014, the number of Ethiopian laboratory tests increased by 122 % – from 3,488 to 7,757 (GIZ 2015). Currently, 13 testing laboratories and nine medical laboratories in Ethiopia are accredited (ENAO 2017c & e). Accredited testing services are mainly concentrated in the capital area, while laboratories in other parts of the country mostly do not have an accreditation (Interview 4).

With regards to the thematic areas considered in this study, the following information is of interest:

- For *renewable energies* and *energy efficiency* there is one accredited laboratory – the previously mentioned electrical testing laboratory of ECAE.
- The majority of accredited laboratories offers services for the *agricultural sector*. There are eight agricultural research laboratories and two food testing laboratories.
- There is currently no accredited laboratory which offers testing services for the *water sector*. (ENAO 2017c). Nevertheless, laboratory facilities offering services for the water sector do exist throughout the country (Interview 4).
- In the *health* sector, one public laboratory with a focus on food science and nutrition in relation to health is accredited.

In February 2017, an Ethiopian Laboratory Association was created (TBT Programme 2017). Any kind of laboratory can join the association and benefit, for example, through joint capacity building activities and cost sharing for reference material or training. The laboratory association works together on the technical level. However, it was mentioned that the laboratory management is not yet sufficiently involved in the activities of the association (Interview 1).

In the health sector, there are several medical laboratory associations. The Ethiopian Public Health Laboratory Association (EPHLA), founded in 2006, aims to advance and maintain a high standard of laboratory services in Ethiopia. The association also supports the national disease control and prevention efforts through improved diagnostic research and surveillance (EPHLA 2017). Similarly, the Ethiopian Medical Laboratory Association (EMLA), established through the Charity and Society Proclamation No 621.2009, envisions attaining an optimal health standard for the country. It participates in medical laboratory standard setting and supports technology transfer to promote emerging technologies. Its further objectives are to improve the evidence-based laboratory practices and to advise private sector actors regarding newly marketed and validated laboratory tests (EMLA 2017).

Certification and inspection

With regards to certification, only two national certification bodies exist. On the one hand, ECAE covers the certification of products (ISO/IEC 17065), systems (ISO/IEC 17021, ISO 14001, ISO 22000, ISO 9001:2008) and persons (ISO/IEC 17024) (ECAE 2017b). On the other hand, the Ethiopian Chamber of Commerce and Sectoral Associations (ECCSA) and sometimes the City Chambers of Commerce and Sectoral Associations if delegated by the National Chamber issue two types of Certificates of Origin. One type of Certificate of Origin is the ordinary and specialized Certificate of Origin which is used in international trade and certifies the Ethiopian origin of a product. The second type certifies that a product satisfies certain criteria according to the rules of origin of the Common Market for Eastern and Southern Africa (COMESA) and specifies whether the product is eligible for tariff reduction or elimination within the region (ECCSA 2017).

Next to local certification bodies, international certification bodies also provide services in Ethiopia. Intertek, for example, certifies food, chemical, textile, leather, plastic, rubber, construction and electrical products (Intertek 2017). Cotecna certifies the conformity of goods and issues certificates of conformity according to Ethiopian Mandatory Standards²⁶, which is needed to clear the shipment at Ethiopian Customs (Cotecna 2017). Bureau Veritas and SGS also represent authorized third-party inspection bodies to approve imported goods at the port of entry on their compliance with the Ethiopian Mandatory Standards list (Bureau Veritas 2013, SGS Group 2017).

Ethiopia has several inspection bodies. ECAE provides ISO/IEC 17020 accredited inspection services for the areas of pre-production, production and pre-shipment. Moreover, it carries out factory evaluations and supervises loading processes (ECAE 2017c). Accredited inspection services for agricultural products are provided by A.Y. Noble Inspection and Surveillance Service, Star Ethiopia P.L.C and Afro Star International Commercial Agency (ENAO 2017d).

26 In 2013, the Ethiopian Ministry of Trade established conformity requirements for certain product categories that are being imported into Ethiopia. The following categories of products are included in the Ethiopian Mandatory Standards list: metrology and measurement equipment, environment, health protection and safety equipment, electrical products, textile and leather products, chemical products (fertilizers, detergents, cosmetics), food products, paper, rubber and plastic products, construction material, solar equipment (Cotecna 2017).

In the thematic areas considered in this study, the following information on certification and inspection services in Ethiopia is relevant:

- Ethiopian Mandatory Standards exist for all thematic areas which require certification (e.g. food products, fertilizers, drinking water, protection and safety equipment and solar equipment) (Cotecna 2016).
- Most certification services and accredited inspection services are available for the agricultural sector.

Accreditation

ENAO was re-established as an independent body in 2012 and is responsible for accreditation in Ethiopia. The organization is placed under the Ministry of Science and Technology and receives government funding to finance its activities. Additionally, some specific activities are funded by donors. Revenues created through accreditation services are collected by the national treasury. Currently, the organization employs 35 internal staff members and 98 external assessors. It is planned to increase these figures (Interview 1).

Accreditation services are available for testing and calibration laboratories (including medical testing), inspection and certification bodies (including product, system and personnel certification). In total, accreditation is available for 52 scopes for laboratories and inspection schemes.

At the moment, one calibration laboratory and 13 testing laboratories, as well as nine medical laboratories have a valid accreditation by ENAO (ENAO 2017a-e). Some of the laboratories have an accreditation for several scopes, resulting in a total of 26 accreditations for testing laboratories and 20 accreditations for medical laboratories. Moreover, four inspection bodies have been accredited (Interview 1).

It is a priority for ENAO to raise awareness among industry actors and create more demand for accreditation services. To achieve this, the organization brings together conformity assessment bodies and industry actors and enables dialogue to ensure conformity assessment services are developed where they are most needed and to encourage industry actors to use existing services. In this way, accreditation becomes more feasible for the service providers (Interview 1).

In the context of climate change, demand for energy certification is rising. ENAO wants to support certification bodies in meeting this demand and is considering introducing accreditation services for greenhouse gas validation and verification bodies according to ISO14065 (Interview 1).

The young and fast-developing organization actively participates in the AFRAC, which it currently chairs. It is an ILAC associate, but is expecting to sign Mutual Recognition Arrangements and become a full member shortly (Interview 1). Until then, some Ethiopian conformity assessment bodies use the services of the South African National Accreditation System (SANAS) for internationally recognized accreditation.

ENAO is involved in a number of bilateral collaborations, including, for example, the training of assessors and study visits from other Sub-Saharan African countries, like Nigeria and Ivory Coast. Strong links have been established with the National Accreditation Bodies of Turkey, Egypt and Kenya (Interview 1).

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Interviewee list

Interview 1: Araya Fesseha, ENAO Director
Interview 2: Endalew Mekonen, ESA Director
Interview 3: Abdu Abagibe, NMIE Director
Interview 4: Sandro Santilli, Co-founder
Rift Valley Water Technology

3.3. Uganda

Authors: Katharina Telfser, Dennis Eucker

3.3.1. Main findings from the Uganda country study

A brief overview of the overall level of relevance of key sectors at the national level, their priority in terms of climate change and opportunities identified for further development of quality infrastructure in Uganda is presented in the following.

Recommendations

Based on the results from the Uganda country study, three main recommendations can be deducted in relation to the overall relevance of analysed key sectors at the national level, their priority in the context of climate change and opportunities for future development of quality infrastructure therein.

1. In Uganda, the forecasted impacts of climate change are taken very seriously. An institutional framework has been built during the past years and relevant policies and strategies are in place. Today, the Climate Change Department (CCD) (under the Ministry of Water and Environment) is in charge of developing, controlling and monitoring strategies and interventions built around both climate change mitigation and adaptation to climate change. From a central perspective, the integration of quality infrastructure aspects has not been considered so far in the country's overall framework of responding to challenges posed by climate change. Creating awareness about the relevance of quality infrastructure and fostering cooperation between the Climate Change Department and the quality infrastructure organizations as an entry point for supporting the development of the needed quality infrastructure services in relevant sectors (particularly agriculture, water and renewable energies) can be seen as an important opportunity in this context.
2. Agriculture remains the main source of livelihood and income for the rural population. At the same time, the sector a) is increasingly affected by climate variability and extremes, while b) agricultural inputs (pesticides, fungicides and climate-robust seedlings) needed for preventing crop damage and losses are of low quality. Basic quality infrastructure services needed by the sector are already offered, but they could be further expanded and improved. Therefore, putting a focus on quality infrastructure services related to climate change in the agricultural sector appears to be most relevant and promising for supporting vulnerable population groups in Uganda. Due to the close linkages between agriculture, water and meteorology, possible joint approaches should be evaluated.
3. A further opportunity for cooperation exists in the renewable energy sector, which represents a focus area of BMZ in Uganda. The importance of expanding and diversifying energy generation from renewable sources to ensure the country's energy self-sufficiency and reduce vulnerability to climate change is understood by Uganda's government. Quality infrastructure services for the sector are currently lacking. The gradual development of necessary services from an early stage of sector development could help Uganda to avoid negative experiences with new technologies, build trust and support their rapid expansion. Especially services in metrology and testing to detect sub-standard product quality of imported goods and for system installation, operations and monitoring are important in this context. This could represent one work package in a project supporting quality infrastructure for adaptation to climate change with a focus on multiple sectors.



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	Relevance at the national level	Priority in climate change context	Opportunities for QI development
Renewable Energies	<ul style="list-style-type: none"> ■ Use of biomass energy in Uganda is unsustainable, and natural resources are continuously depleting. ■ The government is attempting to become energy self-sufficient (focus on hydropower and other renewable energy sources). 	<ul style="list-style-type: none"> ■ With a high dependence on hydroelectricity, the whole power sector suffers from a shortage of generating capacity due to prolonged drought conditions, especially in the northern and north-eastern parts of Uganda. 	<ul style="list-style-type: none"> ■ Currently there is low development of quality infrastructure and limited demand for services. ■ Extension of services is not planned in the near future due to limited availability of funding. ■ Renewable energies and energy efficiency is a focal area of BMZ in Uganda.
Energy Efficiency	<ul style="list-style-type: none"> ■ Energy efficiency has no central priority in Uganda's present energy policy. ■ Currently, there is a strong need to increase the efficiency of energy production and to reduce network losses. 	<ul style="list-style-type: none"> ■ No priority in climate change context. 	<ul style="list-style-type: none"> ■ Low quality infrastructure development status in metrology and testing. ■ Standards as basis for labelling requirement currently under revision. ■ Increase in demand for services is expected.
Meteorology	<ul style="list-style-type: none"> ■ Uganda National Meteorology Authority (UNMA) is important for providing information to most of the key sectors and to the rural farming population. ■ There is a need for a) digitizing climate data, b) increasing the network of weather stations and c) improving their maintenance. 	<ul style="list-style-type: none"> ■ Within UNMA, there is a climate change unit working as "technical arm" of Uganda Climate Change Department. ■ UNMA provides trimestral seasonal weather forecasts to decentralized government structures across the whole country and monitors the success rate of forecasted weather events. 	<ul style="list-style-type: none"> ■ Some basic services offered. ■ Sector is actively looking for international cooperation partners. ■ Potential for stronger collaboration between meteorology and metrology as contact is already established.
Agriculture	<ul style="list-style-type: none"> ■ Even though the vast majority of the Ugandan population depends on agriculture as the main source of its livelihood and income, development of the sector appears not to be important for the government's economic growth strategy (but is rather linked to the poverty reduction strategy). 	<ul style="list-style-type: none"> ■ Agricultural soils of the country are considered rich and fertile, but climate change is forecasted to lead to declining production levels. ■ Need for improved soil and land management, climate-robust seeds, high quality pesticides and fungicides. 	<ul style="list-style-type: none"> ■ Basic quality infrastructure services already offered. ■ Clear priority for improvement and development of additional services. ■ Importance of services in the climate change context well understood. ■ Agricultural and rural finance is a focal area of BMZ in Uganda.
Water	<ul style="list-style-type: none"> ■ Uganda's water sector faces enormous challenges caused by a) the high rate of population growth, b) increasing urbanization, c) pollution of water sources, d) degradation of ecosystems and e) an overall lack of enforcement of water regulations. ■ A national Strategy for the development of the water sector is in place. 	<ul style="list-style-type: none"> ■ Climate change in Uganda a) severely affects water regimes and water resources, b) leads to environmental degradation along with negative social and economic consequences for the population, c) damages the supply infrastructure and d) deteriorates water quality and quantity. ■ Climate change could potentially undermine Uganda's successes made in providing water to its population. 	<ul style="list-style-type: none"> ■ Basic quality infrastructure services offered. ■ Some remaining gaps and opportunities for improvement (e.g. accreditation of testing laboratories). ■ Water and sanitation is a focal area of BMZ in Uganda.
Human Health	<ul style="list-style-type: none"> ■ Achieving Vision 2040 of a healthy and productive population by providing Universal Health Coverage is a key priority of Uganda. ■ Successes were made in terms of reducing maternal mortality and under-five mortality. 	<ul style="list-style-type: none"> ■ Climate change has significant health implications for Uganda. Diseases which are already endemic in some places are expected to proliferate in regions where they have been sporadic so far. ■ There is potential for diseases which are not yet established in Uganda to be introduced because of climate change. ■ Climate change threatens human health through its effects on food security and malnutrition. 	<ul style="list-style-type: none"> ■ Some basic services offered. ■ Limited demand for quality infrastructure services.
Status of relevance/priority/opportunities		High	Medium
			Low

Table 24: Relevance, priorities and opportunities for quality infrastructure development in relation to climate change in Uganda

3.3.2. Uganda's background

Political and economic context of Uganda

Following decades of power struggles after Uganda gained its independence from Britain in 1962, President Yoweri Museveni took over the country's leadership in 1986. Since then, Uganda has rebounded from civil war and economic catastrophe to become relatively peaceful, stable and prosperous. The impoverished northern districts, where until 2009 the Lord's Resistance Army operated under rebel leader Joseph Kony, which have been the scene of much ethnic conflict, have been the focus of reconstruction since 2009 (GIZ 2017).

Uganda needs a renewed growth momentum to achieve its vision of attaining middle-income status by 2022 – this, however, will only be achievable if the economy can grow at annual rates above 10 % per annum (Muloni 2012). Since the late 1990s, the country has experienced sustained economic growth averaging 7 % annually. Since 2010, growth rates have been lower but remained reasonably positive. However, despite economic growth stemming mainly from its natural riches (Uganda has substantial natural resources including oil, natural gas, copper and cobalt), the country's growth has not resulted yet, nor reflected, improvement in the livelihoods of its people. The United Nations categorize Uganda as a least developed country (LDC). Its Human Development Index (HDI) is ranked below its neighbours Kenya, Rwanda and Tanzania and in fact the index is below the Sub-Saharan Africa average of 0.502 (EPRC 2017).

The recent annual economic growth rate of 3.6 %, coupled with high population growth and rising inflation aggravates the situation for the almost 37 million Ugandans. Against this background, it is likely that Uganda is facing poor prioritization of resources. Having plenty of fertile soils and land, agriculture provides jobs for more than 80 % of the workforce, making it the single most important source of income. However, agriculture has remained at rather low values in terms of contribution to Uganda's GDP (22.5 %). In terms of subsistence crops, small-scale and rain-fed farming and livestock production represent the majority of Uganda's agricultural output while, in terms of cash crops mainly being produced for the export market, the country produces coffee, cotton, tea, tobacco and sugarcane.

Evidence of climate change in Uganda

Effects of climate change and relevant hazards

Climate change is expected to adversely impact Uganda by a change in temperature of over 2 °C by the year 2030 while the start of rainy seasons may change by 15 to 30 days and the length of seasons by 20 to 40 days. December, January and February are expected to become wetter. Extreme weather conditions might increase, further exacerbating frequent and severe droughts, floods and unpredictable patterns in rainfall (USAID 2013).

Climate change impacts are therefore likely to exacerbate some existing stresses, for example land degradation. The main impacts however are likely to be (Hepworth 2008:12):

- Increased food insecurity;
- Shifts in areas affected and increased incidence in some areas of diseases, such as dengue fever, malaria and water-borne diseases associated with floods;
- Elevated rates of erosion and land degradation because of increased mean rainfall or higher intensity events;
- Greater risks of flood damage to infrastructure, property and settlements;
- Shifts in the viable area for coffee cultivation with increased temperature;
- Reduced output in the maize crop;
- Reduction in the grazing potential within the cattle corridor;
- Biodiversity loss and extinctions as niches are closed out by temperature increases and pressure on natural resources;
- Implications for Lake Victoria levels and Nile flows.

Impacts of climate change on different areas

Climate change is expected to have severe consequences in all sectors, specifically in the agricultural and water sectors (USAID 2013).

Agriculture and food security: The agricultural sector is forecasted to be particularly susceptible to the impacts of climate change. With agriculture being mainly rain-fed in Uganda, absence of rain can lead to crop failure, food insecurity, famine, mass migration and result in negative national economic growth. Examples cited in the report

were recent poor farm yields and occurrence of pests and diseases, mainly caused by a shift of inter-annual and seasonal precipitation patterns. This is all the more important as agriculture in fact remains the first opportunity to achieve sustained economic growth and well-being of Uganda's poor population, which is predominantly active in the farming sector. However, even without climate change, the agricultural sector is struggling to cope with outdated production methods and the threats of ongoing deforestation and soil depletion.

Water: Climate change in Uganda severely affects water regimes and water resources. This leads to environmental degradation along with negative social and economic consequences for the Ugandan population. Damages of supply infrastructure, same as deteriorating water quality and quantity, are expected for the water sector. Furthermore, climate change could potentially undermine Uganda's successes made in providing water to its population (with 64 % rural access and 72 % urban access in 2014; while at the same time, water supply is lacking behind especially in the northern and eastern parts of Uganda). However, even without climate change representing a new layer of risk, the country's water sector already by now faces enormous challenges caused by the high rate of population growth, increasing urbanization, the pollution of water sources, the degradation of ecosystems such as forests and wetlands and an overall lack of enforcement of water regulations (IWaSP 2017).

Energy: Uganda is heavily dependent on biomass and hydroelectricity for energy production. At the same time, changes in average water (lake) levels will affect the availability of water for hydro-electric power production (Hepworth 2008). Without major investments made in other sources of energy production, including renewable ones, Uganda's energy sector will remain heavily dependent on favourable climate conditions. Decreasing hydroelectricity generation could lead to higher prices and an even greater use of fossil fuels, which increases greenhouse gas emission even further.

Human Health: Climate change has significant direct and indirect health implications for Uganda. Malaria is endemic in 95 % of Uganda and higher temperatures will allow it to proliferate in regions where it has been sporadic. Climate change is also expected to increase the prevalence of many other endemic and imported infectious diseases, such as soil-transmitted helminths, trachoma and

waterborne diseases such as cholera and typhoid. Other diseases which Ugandans experience in a more localized or epidemic nature include plague, sleeping sickness and yellow fever. Additionally, there is also potential for diseases which are not yet established in Uganda to be introduced because of climate change, such as dengue fever, chikungunya and Rift Valley fever. Finally, climate change threatens human health through its effects on food security and malnutrition (Zinszer 2014) and through the direct physical effects of natural disasters.

Institutional and policy framework for climate change adaptation and mitigation

In Uganda, the policy framework for climate change mitigation and adaptation to climate change is mainly based on the goal to "ensure a harmonised and coordinated approach towards a climate-resilient and low-carbon development path for sustainable development (...)" (Mai-kut 2014). The main objective is to "ensure that all stakeholders address climate change impacts and their causes through appropriate measures, while promoting sustainable development and a green economy" (ibid.).

A Climate Change Unit (CCU), now known as the Climate Change Department, as one of the national measures to ensure action was created in 2008, directly under the office of the Permanent Secretary within the Ministry of Water and Environment. The main objective for the establishment of the CCU is to strengthen Uganda's implementation of the UNFCCC and its Kyoto Protocol.

The key functions of the Climate Change Department are, among other areas:

- To play the role of National Focal Point for the UNFCCC and its Kyoto Protocol;
- To coordinate national climate change actions (mitigation and adaptation) in different sectors, including the creation of awareness among various stakeholders;
- To monitor the implementation of mitigation and adaptation activities and progressively update the Ugandan Government, the Uganda population and the COP to the UNFCCC;
- To provide technical support to the Permanent Secretary of the Ministry of Water and Environment to enable him/her to coordinate climate change issues more effectively as part of the mandate of the Ministry;

- To initiate the development and review of appropriate policies, laws and programmes necessary to ensure effective implementation of adaptation and mitigation activities in Uganda.

Considering the cross-sectoral nature of climate change interventions and the broad functions and tasks under the mandate of the Climate Change Department, strategic frameworks have been created, including the Climate Change Policy Committee and the Inter-Institutional Climate Change Technical Committee:

- Climate Change Policy Committee (CCPC): The CCPC, chaired by the Permanent Secretary Ministry of Water and Environment, has 14 members from various public and private institutions. The Commissioner of the Climate Change Department is the Secretary to the Committee. The main functions of the Climate Change Department are:

- To offer policy guidance to the Ministers of Water and Environment on matters related to climate change;
- To assist the Minister of Water and Environment to take decisions on carbon finance activities in her capacity as the CDM Designated National Authority (DNA) for Uganda;
- To reconstitute themselves into a Project Steering Committee to guide implementation of climate change projects in the Ministry;

- Inter-institutional Climate Change Technical Committee (ICCTC): The ICCTC is constituted by the Climate Change Desk Officers from various public and private institutions. Its main functions include:

- Bridging the gap between the Climate Change Department and the respective institutions, facilitating exchange of information and by focusing efforts on:
 - Technical capacity of Climate Change Department, including through increased numbers and skills of personnel as well as equipping the office and scaled up facilitation of operations;
 - Development of a climate change policy and mainstreaming guidance documents to facilitate harmonized national action;
 - Development of climate change awareness raising

materials and the associated strategic awareness creation at all levels;

- Piloting and rolling out National Adaptation Programme of Action (NAPA) implementation;
- Conducting climate change-related research.

Climate change mitigation

In terms of climate change mitigation, the Climate Change Department under the Ministry of Water and Environment serves the following purposes:

“To promote and cooperate in the development, application and diffusion, including transfer of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases in all the relevant sectors including energy, transport, industry, agriculture, forestry and waste management.”

(Ministry of Water and Environment CCD 2017)

Burning of renewable resources provides approximately 90 % of the energy in Uganda (Wandera and Sanya 2015), though the government is attempting to become energy self-sufficient (Muloni 2012). Electricity access is currently below 5 % in rural areas. While the country strongly depends of hydroelectricity for about 60 % of its total power generation output, the whole power sector suffers from a shortage of generating capacity due to prolonged drought conditions, especially in the northern and north-eastern parts of the country.

Whereas in Uganda the Renewable Energy Policy of 2007 reinforces the government’s commitment to the development and utilization of renewable energy resources and technologies, little has been done to attract investment in this area, despite several opportunities in the sector (Muloni 2012). The overall aim is to make renewable energy a substantial part of the national energy consumption and increase its availability. It thus makes a case for stronger investment in the sector, while revealing the relevant aspects of the legal regime governing the sector and the challenge of the un-updated laws.

The government has put in place a comprehensive plan to address the current energy deficit and meet long-term energy needs. The plan is to enhance public-private partnerships in power generation and supply and the sustainability of the power sector.

The strategies include:

- Energy loss reduction in the power system,
- procurement of additional thermal generation capacity,
- energy efficiency/demand side management,
- renewable energy generation projects including small hydro plants,
- cogeneration in sugar mills and biomass-gasification plants,
- promotion of solar water heating in both homes and commercial enterprises, and
- construction of the Bujagali (250MW) and Karuma (150–200 MW) projects.

The long-term measures include development of four large hydropower sites, use of indigenous petroleum resources for thermal generation, interconnection of the regional power grid and the use of geothermal, peat and other renewable sources of energy.

Climate change adaptation

Uganda already developed its National Adaptation Programme of Action in 2007 (The Republic of Uganda 2007). A particular focus for adaptation action has been put on agriculture and on water resources, also as cross-cutting topics. All in all, eight intervention areas are prioritized in the National Adaptation Programme of Action: 1) Land and land use, 2) Farm forestry, 3) Water resources, 4) Health, 5) Weather and climate information, 6) Indigenous knowledge documentation and awareness creation, 7) Policy and legislation and 8) Infrastructure.

In terms of adaptation to climate change, one of the main functions of the Climate Change Department is:

“To prepare for adaptation to the adverse effects of climate change by guiding the development of elaborate, appropriate and integrated plans for key sectors as well as the rehabilitation of areas affected by drought, desertification and floods.”

(Ministry of Water and Environment CCD 2017)

In Uganda, the Climate Change Department plays a central role for the planning and coordination of international cooperation activities related to priority areas identified under the National Adaptation Programme of Action. Presently, four ‘implementing partners’ have been acknowledged by the Climate Change Department to pilot

the implementation of the priority areas identified under National Adaptation Programme of Action. These include the Agency for Sustainable Development (ASDI), the Development Network of indigenous voluntary Associations (DENIVA), the Production Departments of Nakasongola District Local Government and Bundibugyo District Local Government.

Most of the ministries represented in the National Council on Climate Change are in the process of elaborating, or have recently elaborated, guidelines for dealing with the impacts of climate change within the framework of their respective jurisprudence. The elaboration of such guidelines remains the task of individual, sector-specific Focal Points and/or Desk Officers.

The ultimate goal is to develop sector strategies for climate change, yet this process has not started yet in most of the line ministries. Related to these strategies, the Ministry of Agriculture has already started to draft a sector-related national adaptation plan while the Ministry of Health is presently in the phase of preparing health-related vulnerability analyses from the national down to the local level in order to better understand the nature and scope of climate change-related risks.

Even though the relevance of climate change to unfold its negative impacts on sectoral development goals is clear to the vast majority of actors, discussions on how to approach and respond to climate change have not involved aspects of quality infrastructure and quality assurance yet. Subordinated entities, such as quality assurance departments of line ministries, research institutes and laboratory systems are widely kept out of the political discussion.

Considering the prevalence of climate- and climate-related hazards in the Ugandan farming sector in particular, stakeholders are aware of an increasing need for elaborating approaches for dealing with quality challenges: In recent years, crop diseases have increasingly caused damages and destroyed crops while pesticides and fungicides have turned out to be inefficient and not be of necessary quality.

In the context of multilateral and bilateral cooperation in Uganda, activities are manifold in all domains covered by the study presented here, including energy (efficiency), agriculture, water, human health and meteorology – including a vast range of climate change-related projects.

The Climate Change Department under the Ministry of Water and Environment of Uganda monitors all cooperation programmes, projects and interventions of different scope and scale related to climate change mitigation and adaptation to climate change: Currently, 275 projects have been implemented – or are in their implementation phase – by various multilateral and bilateral international cooperation partners and NGOs.

Within this context, there is a clear opportunity for fostering the position and the role of quality infrastructure services and the possibilities it provides to relevant government institutions concerned with climate change.

Multilateral and bilateral cooperation activities

In the National Climate Change Implementation Strategy of Uganda, policy goals and their interrelated objectives are addressed. The Strategy provides a basis for the coordination and cooperation of, and between, multilateral and bilateral donor and funding organizations supporting Uganda's response to challenges posed by climate change.

Multilateral cooperation

United Nations Development Programme (UNDP): UNDP has been active in Uganda for more than four decades. Relevant fields of cooperation and support include renewable energies and energy efficiency, agriculture and meteorology. Three main programmes of UNDP relevant in the context of the study in Uganda are called “Low Emission Capacity Building”, “Adaptation to Climate Smart Agriculture Practices” and “Strengthening Climate Information and Early Warning Systems” (UNDP 2017).

World Bank Group (WBG): Major programmes are currently implemented in areas related to renewable energies, energy efficiency and human health. Among WBG initiatives relevant in the context of this study is the “Uganda Rural Electrification Programme” which was approved in its third phase in 2016 and has a funding volume of USD 13.7 million, the Grid Expansion and Reinforcement Project (GERP) which was also approved in 2016, with the objective of increasing the availability and efficiency of bulk electricity supply in northern Uganda and the West Nile region with a total cost of USD 127.3 million. Additionally, the Reproductive, Maternal and Child Health Services project which has a duration of five years until mid-2021 aims at improved utilization and better access to essential health services with a focus on reproductive, mater-

nal, new-born, child, but also adolescent health service in target districts. The total project cost is USD 140 million (World Bank 2017).

Bilateral cooperation

In 2007, the German Federal Ministry for Economic Cooperation and Development (BMZ) declared Uganda a priority country for development cooperation. At the bilateral negotiations between the Ugandan and German governments held in Kampala in May 2013, both sides agreed that this cooperation should focus on three priority areas:

- Renewable energies and energy efficiency
- Sustainable economic development/rural and agricultural finance
- Water and sanitation

It was also agreed that good governance and adherence to human rights, including the rights of vulnerable groups and sexual minorities, were fundamental principles for Ugandan-German development cooperation.

Further projects are also ongoing in the areas of transparency and accountability, climate change mitigation, the preservation of peace in the country's northern regions and capacity development for evaluation and governance statistics.

German Society for International Cooperation (GIZ): The water and sanitation, energy and agricultural sectors comprise most of GIZ's funding volume in Uganda. Relevant GIZ activities in the agricultural sector focus on a project on “Adapting agricultural cultivation methods of the Kari-mojong to climate change in the Karamoja sub-region”, while activities in the water sector are focussed on and around the programme “Development of the urban water and sanitation sector”. In relation to renewable energies and energy efficiency, GIZ currently implements three major projects, namely “Maximising the benefits of access to energy”, “Promotion of renewable energy and energy efficiency (PREEEP)” and “Global Carbon Market – Uganda”.

German Development Bank (KfW): KfW supports Uganda in areas relevant to the study presented here, including a) drinking water supply and sewage disposal and b) “GET FiT” which is a programme aimed at further development of renewable energies.

3.3.3. Analysis of thematic focus areas

Renewable energies and energy efficiency

Uganda still faces problems in providing universal energy access to its population. Presently, only 15 % of the population is connected to the power grid. In rural areas, the figure drops to 6 %. While demand is growing steadily by around 8 % per annum, as population increases and economy grows, production and transmission capacities are stretched. According to KfW, there is also a strong need to increase the efficiency of energy production and to reduce network losses.

Burning of renewable resources provides 90 % of the energy supply in Uganda. While much of the hydroelectric potential still remains untapped, the government decision to expedite the creation of domestic petroleum capacity coupled with the discovery of large petroleum reserves in northern Uganda holds the premise of a significant change in Uganda's status as an energy-importing country (Grøtnæs et al. 2014).

During the past years, Uganda has been employing a number of different strategies to expand its electricity supply. There is general awareness that the lack of electricity slows down social development and economic growth on the one hand, while widespread use of wood and charcoal accelerates deforestation.

Besides hydropower as a main source for power generation, stronger focus has been put particularly on solar power and energy from the sustainable use of biomass. For promoting the further development of renewable energies, regulatory barriers for private investments are currently in the process of being overcome. Structurally, Uganda's energy sector is increasingly well positioned. The privatization of electricity production and distribution has already led to some initial successes (KfW 2017).

Meteorology

In Uganda, the institution in charge of meteorological services is the Uganda National Meteorology Authority (UNMA), formerly the Department of Meteorology under the Ministry of Water and Environment. UNMA is a semi-autonomous government institution for weather and climate services and a focal institution to the IPCC. With a staff of 192, its mandate is "to monitor weather and climate as well as provide weather predictions and

advisories to the Government and other stakeholders for use in sustainable development of the country" (UNMA 2017q).

UNMA is responsible for establishing and maintaining Uganda's weather and climate observing stations network, collection, analysis and production of weather and climate information, including warnings and advisories. The key sectors served by UNMA include transport (mainly aviation and marine), defence, agriculture, disaster preparedness, environmental and water resources management, tourism and construction industry. UNMA accomplishes these responsibilities in collaboration and coordination with the World Meteorological Organization (WMO) and its member states and other global and regional meteorological centres.

The Meteorology Authority consists of five strategic departments. Within the institutional structure, Applied Meteorology, Data & Climate Services is concerned with monitoring and assessing long-term climatic trends in the country and in the region. Within the department, there is also a climate change unit. Climate data are organized along 14 meteorological zones in Uganda. Data range back to 1896, with most of the data (>60 %) being still "on paper". Supported by GIZ, data are continuously becoming digitized.

The department also provides for Seasonal Climate Outlooks which are published on a trimestral basis and handed over to all parliament members. These publications are translated into 35 local languages. Seasonal Climate Outlooks are prepared by UNMA staff in cooperation with IGAD in Nairobi, Kenya and by sharing data and information at the regional and biannual Great Horn of Africa Climate Outlook Forum.

Meteorological information is mainly gathered through 80 weather stations (48 are manual and 32 are automatic). It is obvious that the stations network was severely impacted by twenty years of civil war and a severe lack of maintenance during that time – until the 1970s, the stations network consisted of more than 1,000 weather stations. For the time being, the priorities of the Government of Uganda for the meteorological sector are a) to continue digitizing historic climate data, b) to increase the network of weather station, c) to improve management and maintenance services for the country's network of weather stations and d) to develop cooperation and exchange with

international partners and meteorological service departments.

Water

Over the last decade, Uganda has made great strides in providing water to its population (with 64 % rural access and 72 % urban access in 2014) (IWaSP 2017:1). However, the Government of Uganda already sought to achieve its national goal of providing 100% of its urban population with an improved water source and access to safe, hygienic sanitation facilities by 2015. In terms of sanitation, 84 % have access to sanitation facilities which are often of questionable hygiene. Only 6 % are connected to a sewerage system.

Urban Uganda is still characterized by inadequate sanitation services and high population growth rates. Increasing urbanization adds to the fact that, especially in poor urban areas and informal settlements, access to sanitation is inadequate and collection, transport as well as treatment of faecal sludge remain great challenges (GIZ 2016c:1).

The situation is even more dramatic in rural Northern and Eastern Uganda. Twenty years of civil war and ethnic conflict have resulted in a severe lack of water infrastructure and sanitation facilities, which means that people often fall sick and cannot look after their families. According to official data, twice as many people suffer from diarrhoea in Northern and Eastern Uganda than in other regions. Diarrhoea leads to malnutrition and contributes to a high infant mortality rate (KfW 2016a:2). Just under one third of the urban population has access to clean drinking water, compared to more than 70 % within the whole country (KfW 2016a:1). In addition, the lack of access to safe drinking water is a threat to food security (KfW 2016a:1).

It remains clear that the sector needs to improve further on its institutional, regulatory and managerial capacities (GIZ 2016a:1). Indeed, the Government of Uganda initiated reforms in the urban water supply and sanitation sub-sector with the long-term objective of providing sustainable and affordable water supply and sanitation services to all segments of the population living in urban areas. The major elements of these reforms were the commercialization of water supply and sewage service operations and the promotion of private sector participation in delivery of services which follows the regime of regulation by contract (GIZ 2016b:1).

Large and highly expensive investments into infrastructure are needed, such as an ongoing programme for providing water for two million more people in Kampala by 2025 than today. In reality, this means that the water treatment capacity must be increased by a total of 165 million litres per day. This is being done by the rehabilitation of existing water plants on Lake Victoria and by constructing a new water treatment plant in the east of the city (KfW 2016b:2). This is even more necessary since other existing sewage treatment plants are already over 70 years old and no longer have sufficient treatment capacity (KfW 2016c:1).

Agriculture

According to the 2016 Agriculture Sector Strategic Plan (Ministry of Agriculture, Animal Industry and Fisheries 2016), the agricultural sector average growth rate was 2.2 % between 2010 and 2015. It was lower than the average annual GDP growth rate of 5.2 % during that time and the average annual population growth rate of 3 % over the same period. Overall, the contribution of the agricultural sector to GDP declined from 25.4 % in 2010 to 23 % in 2015. Agriculture has remained at rather low values in terms of contribution to Uganda's GDP, but is the single most important source of income as it provides jobs for more than 80 % of the workforce (with small-scale and rain-fed subsistence farming and livestock production representing the majority of Uganda's agricultural output).

Gains were especially made in the production of five major commodities (coffee, tea, cotton, cocoa and milk). Out of 16 major food crops, only five registered an increase in yields, i.e. maize, potatoes, beans, cow peas and sesame seeds, while cereals, sugarcane, root crops and bananas remained relatively stable – but some of them even declined in yields, particularly in some areas and regions. This means that even without climate change, the agricultural sector is struggling to cope with outdated production methods and the threats of ongoing deforestation and soil depletion. Other challenges include poor post-harvest handling and processing constraints; poor stakeholder coordination – including public-private partnerships; human resource challenges including inadequate staff, lack of training and poor equipment; poor markets and marketing infrastructure; and funding constraints.

Human Health

The Health Sector Development Plan for Uganda (Ministry of Health 2015), which sets the country's medium-term strategic direction, development priorities and implementation strategies, is the second in a series of six 5-year plans aimed at achieving Uganda Vision 2040 of a healthy and productive population which contributes to socio-economic growth and national development. The goal of this Plan is to accelerate movement towards Universal Health Coverage (UHC) with essential health and related services needed for the promotion of a healthy and productive life.

The achievements realized under the sector development plan include among others:

- The reduction in maternal mortality ratio from 438/100,000 (UDHS) live births in 2011 to 360/100,000 (WHS estimates) live births in 2014;
- The reduction in under-five mortality from 128/1000 live births in 2006 to 90/1000 live births in 2011 to 69/1000 (WHS estimates) live births in 2014 and the reduction of the infant mortality rate from 71/1000 live births in 2006 to 54/1000 live births in 2011 and 45/1000 (WHS estimates) in 2014.

The impact of all this has been an improvement in the life expectancy at birth in Uganda, from a low of 47 and 45 years in 2000/01 for females and males respectively, to 57 and 54 years in 2011, and estimated to have improved further since then.

HIV, malaria, lower respiratory infections, meningitis and tuberculosis still are estimated to cause the highest numbers of lost life years in Uganda. In addition to these major causes, the sector has faced challenges with new/re-emerging conditions which cause minimal burden but are significant public health risks, e.g. polio, hepatitis E & B, Ebola, Marburg virus and the idiopathic nodding syndrome.

With health infrastructure, physical access to health facilities (the proportion of the population living within 5 km of health facility) is currently at 72%. Despite this, there are also still major inequities in the availability of facilities, ranging from a low of 0.4 facilities per 10,000 citizens (Yumbe district) to a high of 8.4 facilities per 10,000 citizens (Kampala). A number of health facilities were renovated and equipped, though they still face the challenges

of inadequate and poorly maintained medical equipment. At the same time, the health workforce is still a key bottleneck for the appropriate provision of health services, with challenges in adequacy of numbers and skills, plus retention, motivation and performance challenges.

To date, the pharmaceutical sector has made an improvement in the availability of and access to Essential Medicines and Health Supplies from 43% in 2009/2010 to 63.8% in 2014/2015. There has been an increase in funding for medicines through both the Government of Uganda and donor streams from USD 92 million to USD 410 million (including USD 85 million for procurement of Long Lasting Insecticide Nets) over the same period, resulting in increased public confidence in the health system. However, the greater proportion (81%) of this funding was from Development Partners and largely skewed to HIV/AIDS, malaria and tuberculosis.

Against this background, the Plan sets key objectives to be attained during the 5-year period. These include: (i) contributing to the production of a healthy human capital for wealth creation through provision of equitable, safe and sustainable health services; (ii) increasing financial risk protection of households against impoverishment due to health expenditures; (iii) addressing the key determinants of health through strengthening inter-sectoral collaboration and partnerships; and (iv) enhancing health sector competitiveness in the region and globally.

In order to achieve these objectives, the strategy for the health sector will be to work towards strengthening the national health system including governance; disease prevention, mitigation and control; health education and promotion; curative services; rehabilitation services; palliative services; and health infrastructure development.

3.3.4. Quality infrastructure services in relevant areas

Quality policy, regulation and important institutions

As outlined in the Ugandan Standards Act of 1983, the Uganda National Bureau of Standards (UNBS) is the centralised body for quality assurance services in the country (Uganda Parliament 1983). UNBS covers standardization, metrology (including legal metrology), testing, inspection and certification. It is headed by the National Standards Council and amounts to over 300 employees.

QI status	Metrology	Standardization	Testing	Certification and inspection	Accreditation
Renewable energy					
Energy efficiency					
Meteorology					
Agriculture					
Water					
Human health					
Quality infrastructure development status	High	Medium	Low	No information	

Table 25: Development of quality infrastructure in relevant sectors

UNBS receives funding by the national government. According to the report of the auditor general, government funding amounted to approximately 12.5 billion Ugandan Shillings (UGX) (approx. EUR 3 million) in 2015, 80% of which was being used to cover staff salaries. In the same year, the bureau collected non-tax revenue (fees for calibration, laboratory testing, training and consultancy) of 7.8 billion UGX (EUR 1.8 million). (Office of the Auditor General Uganda 2015). The organization's own financial resources generated through the provision of services in the different areas are steadily increasing and now (mid-2017) make up approximately 50% of the budget. Nevertheless, the current levels of funding are insufficient to support the needed development of additional services, the procurement of the necessary equipment and active participation in international organizations.

The Bureau has two directorates and various support functions. The Standards and Compliance Directorates carry out the main quality infrastructure functions and are supported by the following six units: management and financial services, public relations and marketing, quality management, procurement and disposal, the legal office and the internal audit division. It has recently undergone internal restructuring, resulting in the following departments under the Standards Directorate:

- Standards Development Department
- National Metrology Institute
- Testing Department

- Certification Department
- Training and Consultancy

The Compliance Directorate comprises the following:

- Legal Metrology Department
- Imports Inspection Department
- Surveillance Department

The restructuring was carried out in preparation for a more radical reform of the national quality infrastructure and should ultimately facilitate a smooth splitting of the different quality infrastructure functions. Particular emphasis is put on the need to separate standards development from the regulatory function. The legal documents for the restructuring, including a national metrology bill that will establish a separate national metrology institute, have already been drafted and presented to parliament.

Parallely, a draft bill on accreditation and conformity assessment has been submitted to government and is expected to be approved by the end of 2017. With this, the establishment of a National Accreditation Body under the Ministry of Trade, Industry and Cooperatives can be completed. The foundations for this process were already laid through the creation of a National Accreditation Focal Point in 2012, as well as through the National Accreditation Policy published in 2014 (Ministry of Trade, Industry and Cooperatives 2014).

Moreover, a National Standards and Quality Policy has been adopted in 2012, based on which a strategic plan for quality infrastructure is under development (Ministry of Trade, Industry and Cooperatives 2012).

Metrology

Metrology department of UNBS

The metrology department of UNBS is the national metrology institute of Uganda. It offers basic calibration services for mass, volume and temperature. For these three measurements, quality management systems are in place and intercomparison measurements are carried out with other national metrology institutes of the East African Community (EAC). The mass laboratory is accredited by the South Africa National Accreditation System (SANAS); renewal of the accreditation will be required (SANAS 2011). Additional services are available in different areas, including pressure, flow, moisture, photometry and electricity. The metrology department has nine laboratories. Some services are offered in collaboration with the testing laboratories of UNBS (e.g. chemical metrology and electricity), which will be integrated into metrology when the organization is restructured, and with some sector-specific laboratories run by ministries (e.g. Ministry of Energy for petroleum). The metrology department's services are accepted by SANAS to provide traceability for Ugandan conformity assessment bodies which seek internationally recognized accreditation.

The metrology department itself has a total of eight employees who are sometimes supported by research assistants or interns.

It is a member of AFRIMETS (AFRIMETS 2017). Moreover, it is planned that the metrology department will join BIPM as an associate member when the necessary funds are available.

Legal metrology

UNBS is also in charge of legal metrology, which is regulated with the Weights and Measures Act Cap. 103 from 1965 and related amendments (ULII 1965). The five main legal metrology offices are located in Kampala, Jinja, Mbarara, Mbale and Lira. The department also has a Pre-package Control division and a Volume and Flow division (UNBS 2017). In total, it has approximately 40 employees who work throughout the country. UNBS' legal metrology

department is a corresponding member of OIML (OIML 2017).

The department verifies weights and weighing equipment including spring balances, platform scales, weights (class M2 and M3), automatic weighers and weigh-bridges. The Volume and Flow division verifies fuel dispensers, depot meters, dispensers and pressure gauges. Correct labelling and quantities in prepackaged goods are checked by the Prepackage Control division. Additionally, measures of length and electricity meters are verified. Expanding UNBS' services to the verification of water meters is under discussion (UNBS 2017).

Relevant metrological services offered by UNBS

In the thematic areas considered in this study, the following metrological services are of interest:

Renewable energy and energy efficiency

Basic metrological services in the area of electricity are available and the legal metrology department carries out verification of electricity meters. Specific services for renewable energies (e.g. calibration of pyranometers to determine solar irradiance) or energy efficiency of fridges and air-conditioning systems cannot be provided at the moment.

Meteorology

UNMA uses calibration services for thermometers and has also contacted UNBS for additional calibration services. So far, collaboration has been limited, as most equipment of UNMA is calibrated in-house by the Directorate of Station Networks and Observations and UNBS does not have the necessary equipment to calibrate advanced technologies. Nevertheless, stronger collaboration between the two institutions could be developed.

Agriculture

Agriculture is one of the focus areas of UNBS. The metrology department currently offers relevant services in mass and temperature. The improvement of moisture meter calibration was mentioned as a priority. This is relevant for many important crops for local consumption and export, including grains and coffee beans. In the area of chemical metrology, some services are offered in collaboration with UNBS' chemical testing laboratory (e.g. pH, purity of honey).

Water

For the water sector, UNBS provides services in volume. Moreover, UNBS has a test bench for water meters which allows the calibration of 0.5 to 2-inch meters. In some cases, the equipment has been adapted to calibrate larger meters. The National Water and Sewerage Corporation currently calibrates the water meters it uses itself. Third-party verification by UNBS is under discussion. For humidity measurements, UNBS owns calibrated humidity meters which are used to qualify the meters brought in by clients. Basic services are also available for pH and conductivity in collaboration with UNBS' chemical laboratory. Most services for this sector are currently not internationally recognized.

Human health

The metrology department receives medical laboratory equipment, such as timers and pipettes for calibration.

Standardization

The Standards Development Department of UNBS is responsible for standardization. At the moment, the department is responsible for both voluntary and “compulsory” standards. With the planned restructuring of the organization, the standard development and regulatory functions will be separated.

The Standards Development Department heads the current 18 national Technical Committees. Private actor involvement in standardization processes has been increasing over the years, as industry actors are gaining a better understanding of the use of standards and are recognizing their importance. Priority areas are agriculture-based trade-related products, steel, textiles and furniture, where the development of small and medium enterprises (for steel, textiles and furniture) is promoted by the government. Nearly 3,000 standards have been developed or adopted so far (UNBS 2016).

UNBS is a member of the ISO, where it participates in 26 and observes 18 Technical Committees (ISO 2017). It is also a member of the ARSO, as well as the EASC. Further, UNBS is the National Contact Point for the Codex Alimentarius Commission and National Enquiry Point for the WTO TBT agreement (UNBS 2016).

With regards to the thematic areas considered, the following can be highlighted:

Renewable energies

Standards for renewable energies are developed by the Technical Committee for electrotechnology. A number of specific standards for solar photovoltaic and solar thermal collectors have already been developed (UNBS 2016). The possibilities to conduct tests against these standards in the country are, however, very limited (see section “Testing” below).

Energy efficiency

Standards for energy efficient devices including light bulbs, refrigerators and motors are currently being reviewed. On this basis, it is planned to introduce a regulation for product labelling. The previously developed standards under an initiative of the United Nations Industrial Development Organization (UNIDO) in collaboration with other countries in the region (see section 3.1 on Kenya) were too stringent for local producers. Also testing against the standard requirements is a challenge, as for some devices necessary testing equipment is not available in Uganda (see section “Testing” below).

Agriculture

As mentioned before, agricultural products are one of the priority areas of UNBS. Over 800 of the nearly 3,000 available standards are related to agricultural produce. Additionally, standards for agricultural machinery and fertilizers are available. At the moment, there is only one standard for bio-pesticides but no standard for conventional pesticides (UNBS 2016). This is an area where improvement is needed, as it was mentioned that pest infestations are increasing due to altered weather conditions caused by climate change (also see the section on “Testing” below).

Water

Relevant standards for water quality are available. The development of national standards for the construction of water reservoirs is supported by the GIZ.

Human health

There is a Technical Committee for medical devices, but at the moment, only a limited number of standards for medical facilities and equipment are available (UNBS 2016). Next to standards developed under UNBS, the Ministry of Health has defined “Service Standards and Service Delivery Standards for the Health Sector”. This publication of the Ministry of Health is thought to guide the public health sector in improving quality, safety and the reliability of its services (Ministry of Health 2016).

Testing

Uganda has a limited number of testing laboratories which are mainly run by ministries and universities. A laboratory network or association does not exist. Only a few testing laboratories are accredited: the chemistry and microbiology laboratories of UNBS, four laboratories of the Ministry of Health and some private ones. While several other laboratories are interested in internationally recognized accreditation, the necessary funds are often not available.

Private testing laboratories are mainly run by international conformity assessment providers such as SGS, Bureau Veritas and Intertek (Logistics Capacity Assessments Wiki 2017). Chemiphar is an example of a private laboratory with international accreditation by the Belgian Accreditation Body (BELAC) (Chemiphar 2017a). The laboratory carries out microbiological, chemical, physical-chemical and environment analyses, as well as seed, grain and pulse testing and also tests improved cook stoves (Chemiphar 2017b).

Important public laboratory facilities are the laboratories of UNBS and the Government Analytical Laboratories under the Ministry of Internal Affairs.

UNBS Testing Department

UNBS has four testing laboratories focussed on chemistry, microbiology, electricity, materials and engineering. The chemistry and microbiology laboratories are ISO 17025 accredited by SANAS. Their services are focussed mainly on food products and water. For microbiology, the following scopes have been accredited: staphylococcus aureus, salmonella, vibrio cholerae, escherichia coli, total plate count, total coliforms, yeast and moulds. The accreditation scope for chemistry includes the following:

- Calcium, potassium, sodium and metals for water
- Moisture content for honey
- Ash, moisture and protein content for cereal foods
- Metal detection in fruit and vegetables.

(UNBS 2017 b, c)

Government Analytical Laboratory Department of the Ministry of Internal Affairs

The government analytical laboratories were set up in 1927 and are seen as a reference for laboratory services in Uganda. There are two departments: quality and chemical verification, and criminalistics, both with four divisions.

They cover pesticide residues, water and environment, food and drugs, microbiology and bioterrorism on the one hand, and toxicology, forensics, fraudulent documents and digital fraud on the other. The department also offers some services in regional laboratories and is working on expanding these services. The accreditation process for the laboratories in Kampala has been initiated with KENAS.

For the selected thematic areas, the following information about testing capacities in Uganda is relevant:

Renewable energies and energy efficiency

Testing services for renewable energies and energy efficiency are very limited. Some tests are carried out by the electrical laboratory of UNBS. However, equipment is lacking for many tests. Performance tests of solar photovoltaic modules, for instance, are carried out using sunlight instead of a sun simulator. Climate chambers for testing the efficiency of refrigerators and air-conditioners, for example, are not available.

Meteorology

UNMA runs 80 manual weather stations and 32 additional automatic weather stations are being installed in collaboration with GIZ. This will increase the amount of available meteorological data in the future and, at the same time, increase the demand for calibration services (for example for temperature, humidity, pressure and wind speed).

Agriculture

A number of laboratories for food, pesticide and fertilizer testing are available and some laboratories are internationally accredited for such services. The National Agricultural Research Organisation (NARO) conducts soil analysis. Overall, however, testing capacities and capabilities for the agricultural sector could be improved. It was particularly pointed out that testing for active ingredients in pesticides must be increased. Negative experiences with new pests have been made in recent times probably due to altered climatic conditions which could not be controlled with applied pesticides as the active ingredient levels were too low.

Water

The accredited chemical and microbiological laboratories offer some testing services for the water sector. The National Water and Sewerage Corporation monitors water quality and the Directorate of Water Resource Develop-

ment under the Ministry of Water and Environment is responsible for the assessment of water availability and abstraction. The laboratories of both institutions are still lacking accreditation.

Human health

Compared with other sectors, the health sector has the most accredited laboratories, including the Central Public Health Laboratory, the medical testing laboratory of the National Tuberculosis and Leprosy Control Program and the Ebenezer Limited Clinical Laboratory – all three accredited by SANAS (SANAS 2017). The National Drug Authority tests drugs and devices.

Certification and inspection

Certification and inspection are mainly carried out by government institutions to confirm compliance with compulsory standard requirements or regulations.

As outlined in the Certification Regulation 1995, UNBS carries out product certification to ensure that safety and quality requirements defined in compulsory national standards are met. When this is the case, the product is labelled with the Uganda Standards Certification Mark, also referred to as the quality and safety mark (UNBS 2017d). In the policy development for “buy Uganda build Uganda” it was identified as a weakness that the certification process is costly and laborious and that it is difficult for local micro, small and medium enterprises to comply with requirements (Ministry of Trade, Industry and Cooperatives 2014b).

UNBS also offers systems certification for:

- Food Safety Management Systems (US-ISO 22000:2005)
- Hazard Analysis Critical Control Points (HACCP) Systems (US 130:1999)
- Quality Management Systems (US-ISO 9001:2000 and 9001:2008)
- Environmental Management Systems (ISO 14000)
- Occupational Health and Safety Management Systems (ISO 18001) (UNBS 2017e)

Inspections of imports to Uganda are carried out at the point of entry and in some cases, additional measures such as a Pre-Export Verification of Conformity (PVoC) or destination inspection are required and a Certificate

of Conformity (CoC) needs to be issued. In these cases, UNBS collaborates with international conformity assessment bodies such as Intertek, SGS and Bureau Veritas (CMA CGM 2013).

With regards to the thematic areas considered in this study, the following information is of interest:

- In the area of energy efficiency, electric appliances are inspected to prevent inefficient products from entering the market. Very inefficient refrigerators, for example, are banned. Furthermore, for renewable energies, components are inspected, and substandard quality products are seized and eliminated. In 2016, for example, 1,090 business outlets were inspected and goods worth 6 billion UGX (EUR 1.4 mio.), including solar panels, batteries, compact fluorescent lamps and blenders were destroyed (UNBS 2017f).
- Food products and agricultural equipment as well as agrochemicals undergo inspection and certification according to national requirements. The Ministry of Agriculture carries out seed certification to ensure the quality of seeds used. Moreover, the Agricultural Chemicals Board carries out inspection on pesticides. However, due to limited capacities often it is merely a visual inspection, which has resulted in substandard-quality products being sold.
- For drinking water, compulsory national standards need to be met and companies are required to undergo certification by UNBS. The National Water and Sewerage Corporation is certified in accordance with ISO 9001:2008.
- For medical supplies in the human health sector, the National Drug Authority is in charge of quality assurance for drugs and medical devices. In addition to tests upon arrival, factory inspections also are carried out.

Accreditation

Accreditation-related matters are currently handled by the National Accreditation Focal Point (NAFP), which was established in 2012 under the Ministry of Trade, Industry and Cooperatives. The set-up and development of the NAFP has been supported through the Quality Infrastructure and Standards Programme (QUISP) in collaboration

with the Swedish International Development Cooperation Agency (SIDA).

The NAFPP collaborates with KENAS and has approximately 40 trained assessors for laboratory accreditation in accordance with ISO 17025 and about 20 assessors for the accreditation of inspection bodies in accordance with ISO 17020.

As mentioned above, the establishment of a National Accreditation Body is underway. It is planned to focus on services which can complement the partner organization KENAS. A challenge will be to generate sufficient demand for accreditation services in Uganda and neighbouring countries.



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3.4. Benin

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3.4.1. Main findings from the Benin country study

A brief overview of the overall level of relevance of key sectors at national level, their priority in terms of climate change and opportunities identified for further development of quality infrastructure in Benin is presented in the following table.

Recommendations

Based on the results of the Benin country study, three main recommendations can be identified in relation to the overall relevance of analysed key sectors at the national level, their priority in the context of climate change and opportunities for future development of quality infrastructure therein.

1. In Benin, a national policy framework for dealing with both mitigation and adaptation to climate change exists. The institutional set-up for developing and coordinating initiatives and cooperation projects has been developed and is in place. However, given the limited financial and human resources available, interventions have been limited in scope and size. In many cases, pilot projects have thus far aimed at broadening the knowledge basis and experience of the Government of Benin. Against this background, any initiative for supporting the development of quality infrastructure services relevant for climate change mitigation and adaptation to climate change should be developed in close cooperation with the relevant institutions of the country and put a focus on capacity building and awareness raising.
2. Both the overall socioeconomic development strategy and climate change policy in Benin put their focus on the agricultural sector. Hence, a collaboration for strengthening quality infrastructure services should preferably focus on objectives which will support sustainable agriculture and economic growth, and which are also in line with the country's climate change tar-

gets. In the dynamic context of Benin's agricultural sector, in which cotton is the predominant export crop, linkages should be identified between the farming sector, water supply and meteorology.

3. Given Benin's important role as a transit country which is highly dependent on market dynamics in its neighbouring countries, a strong regional perspective for fostering quality infrastructure development should be taken. In this context, the Economic Community of West African States (ECOWAS) plays an important role. The specific needs in the region to address climate change could be considered in the follow-up project supporting quality infrastructure in the ECOWAS region. A triangular cooperation project with another country in the region, which already has more advanced quality infrastructure services, could also be of interest. With Tunisia and Morocco, for instance, connections are already established and collaborations in different areas (metrology, certification, including accreditation) are being considered.

3.4.2. Benin's background

Political and economic context of Benin

Transition from Marxist-Leninist single party-rule to democracy in Benin went smoothly and peacefully in the late 1980s (BMZ 2017). Politics in Benin are placed in a framework of a multi-party, presidential representative democratic republic, where the President is both head of state and head of government. The country's political system is derived from the 1990 Constitution and the subsequent transition to democracy in 1991.

Presidential elections held in March 2016 were won by the multi-millionaire and cotton sector tycoon, Patrice Talon. In December 2016, the new government adopted an ambitious development programme called "Programme d'Actions du Gouvernement" structured around 45 flagship projects aimed at improving the productivity and living conditions of the population (World Bank 2017).

Benin's economy has continued to grow stronger over the past years, with real GDP growth estimated at 4–5% over the past decade. The main driver of growth is the agricultural sector, with substantial employment and income

	Relevance at national level	Priority in climate change context	Opportunities for quality infrastructure development	
Renewable Energies & Energy Efficiency	<ul style="list-style-type: none">■ The Government of Benin puts a focus on improving the overall energy supply system, the quantity and the quality of energy sources and on enhancing the efficiency of energy supply and demand.	<ul style="list-style-type: none">■ Some donor organizations support the Government of Benin in promoting renewable energies and high-performance economical homes, particularly in areas vulnerable to climate change, but there is no clear priority when compared to other sectors.	<ul style="list-style-type: none">■ Only basic services exist and there is no priority for future development.■ No priority in the context of multi- and bilateral donor cooperation.	
Meteorology	<ul style="list-style-type: none">■ Basic meteorological services exist for providing daily weather forecasts.	<ul style="list-style-type: none">■ Basic meteorological services exist; bulletins for seasonal weather forecasting are being published.	<ul style="list-style-type: none">■ Basic metrological services exist and improvement is planned.	
Agriculture	<ul style="list-style-type: none">■ The agricultural sector is considered the main driver of growth for Benin, with substantial employment and income arising from farming (mostly cotton).	<ul style="list-style-type: none">■ Benin's economy is primarily based on agriculture which is mainly rain-fed. Climate change therefore has important impacts on the agricultural sector.	<ul style="list-style-type: none">■ Several relevant metrological services are offered and planned to be developed. Relevant standards exist, but implementation lacking.■ Agriculture is one of three priority areas for BMZ in Benin.	
Water	<ul style="list-style-type: none">■ The further development of the water sector is a priority area for the government of Benin.■ Steady and ongoing progress has been experienced in improving the population's access rate to safe drinking water.■ However, many challenges persist concerning improvements in sanitation infrastructure.	<ul style="list-style-type: none">■ With very little research available, the results from existing studies reveal that the pressure on Benin's water resources might increase, leading to greater competition for surface water.	<ul style="list-style-type: none">■ Some relevant testing laboratories exist. There is a need for expansion of services and support in implementing quality management systems.■ Relevant standards exist, but implementation is lacking.■ Water and sanitation is one of three priority areas for BMZ in Benin.	
Human Health	<ul style="list-style-type: none">■ Ongoing improvement in the country's health care indicators and improvement in health care efficiency and cost.■ The focus of the Ministry of Health is on reducing preventable deaths among vulnerable populations in Benin.	<ul style="list-style-type: none">■ There is an emphasis on the country's overall approach to dealing with the high prevalence of malaria and subsequent high number of malaria morbidity and mortality.■ Climate change is expected to undermine successes made so far in reducing the number of malaria cases.	<ul style="list-style-type: none">■ New regulation for blood pressure meter verification is planned.■ Important testing capacities for food safety and public health are lacking.	
Status of relevance/priority/opportunities		High	Medium	Low

Table 26: Relevance, priorities and opportunities for quality infrastructure development in relation to climate change in Benin

arising from subsistence farming, and with cotton being the country's main export – accounting for roughly 40 % of GDP and 80 % of official export receipts (WITS 2017).

Services and regional trade contribute the largest part of GDP because of Benin's geographical location as a coastal country in the centre of Western Sub-Saharan Africa. Benin's industrial sector is not particularly well developed and focusses mainly on cement production, cotton ginning and wood processing (BMZ 2017).

Evidence of climate change in Benin

Effects of climate change and relevant hazards

In addition to being susceptible to multiple exogenous shocks, including in terms of trade shocks (cotton and oil prices) and developments in its neighbouring countries, Benin is also vulnerable to climate change. Available evidence suggests that the most certain manifestation of climate change on precipitation is an increase in variability while the directions of changes are much more uncertain.

Medium-term climate projections for the country's territory indicate important risks of insufficient levels of rain, increased evapotranspiration and more rainfall variability from one year to the next. Therefore, droughts are more likely to become more and more intensive (UNDP 2017).

These predicted changes in climate, despite uncertainties, are likely to have an impact on farmers who engage in subsistence or rain-fed agriculture, the landless who are usually dependent on on-farm labour opportunities and female headed households (UNDP 2017).

Additionally, coastal areas are expected to experience a sharp rise in sea level. The latter is expected to threaten the people living along the coast where both income and population density is higher than in other parts of Benin. Both biophysical and socioeconomic vulnerability is high due to limited adaptive capacity (MER 2015:1). The continued advance of the sea, coastal erosion and the rise in sea level, exacerbated by human activity on the coast, have medium- and long-term consequences which are already threatening vulnerable communities and disrupting the least-protected sensitive ecosystems (UNDP 2017).

Given these facts, the Government of Benin has identified droughts, floods, sea-level rise and late and violent rains as the main climatic risks (Dossou 2009).

Impacts of climate change on different areas

Climate change is expected to have severe consequences on Benin's socioeconomic development situation and on the environment. The expected impact of climate change, especially the projected rise in temperature and rainfall is likely to intensify the challenges already faced by the agriculture and other sectors, including (regional) services, trade and transport.

Agriculture and food security: Benin's economy is primarily based on agriculture which is mainly rain-fed. Climate change therefore has important impacts on the agricultural sector. Agro-climatic parameters are constraining for the agricultural and forestry sector, especially in the southwest and in the far north, regions which suffer frequent droughts. Rainfall has generally decreased over the past decades, leading to a reduction in the length of the agricultural season. Rainfall regimes and agricultural production systems are therefore modified.

Water: Few studies exist so far on how the water sector will be impacted by climate change in Benin. A study conducted by Höllermann et al. (2010) suggests that, generally, annual water availability per capita far exceeds the critical threshold of about 1,700 m³. But during the dry season, water scarcity occurs at the local scale. By aiming at analysing Benin's future water situation under different scenarios of socio economic development and climate change until 2025, results from the study show that the pressure on Benin's water resources will increase, leading to greater competition for surface water. Furthermore, financial and technological constraints hinder satisfactory development and exploration of groundwater and reservoir resources. The study concludes that improvements are most needed, especially in rural areas.

Energy: Climate-induced pressures negatively impact the energy sector in Benin. As average temperatures rise, the demand for electricity is increasing – as more intensive and longer use of air conditioning, ventilation and refrigeration are needed. Coupled with inefficient household and commercial equipment and the inefficient lighting of buildings, there are critical imbalances in the energy sector (UNDP 2017) which will be further aggravated by climate change.

Human Health: While the overall impact of climate change on human health in Benin has not been the focus of many analyses yet, Dossou (2009) describes in a study about ma-

laria in Cotonou how the disease may mutate and increase in the future due to climate change. The author describes how malaria constitutes a major public health problem in Benin where the disease occurs all year round. Malaria is particularly prevalent in areas subject to flooding and one immediate consequence of an increase in flood frequency is an increase in mortality due to malaria. Malaria is the cause for 34 % of medical consultations and 20 % of hospital admissions. It is the principal cause of mortality in Benin, causing more than 1,000 deaths per year.

Additionally, the economic implications of malaria for Benin are enormous. With climate change predictions suggesting temperature increases of between 1–2.5 °Celsius by the year 2100, an increase in temperature could lead to the expansion of ecological zones suitable for the Anopheles mosquitoes, which carry malaria. Malaria therefore needs to be considered with special caution when analysing climate change impacts on human health in Benin.

Institutional and policy framework for climate change adaptation and mitigation

The Government of Benin takes a proactive and comprehensive strategic approach for responding to the forecasted impacts of climate change. Climate change is a major development concern for Benin due to its impacts on human health, food security, economic development, physical infrastructure and water resources. Benin's climate action plan – including the Intended National Determined Contributions (INDC) – was submitted to the UNFCCC ahead of the COP21 Paris Agreement (UNFCCC 2017).

The Ministry of Environment, Climate Change Management, Afforestation and Protection of Natural and Forest Resources (Ministère de l'Environnement Chargé de la Gestion des Changements Climatiques, du Reboisement et de la Protection des Ressources Naturelles et Forestières) of Benin is in charge of developing and coordinating the national climate change action plan. Besides the National Adaptation Programme of Action (NAPA) and the country's Intended National Determined Contributions, a national strategy which is called "Stratégie nationale de renforcement des ressources humaines, de l'apprentissage et du développement des compétences pour favoriser un développement vert, faible en émissions et résilient aux changements climatiques" has been adopted by the Government of Benin in 2013 with the aim to develop necessary skills and knowledge to effectively respond to the challenges posed by climate change.

Key sectors in which climate change-related initiatives have been and will be further developed primarily include agriculture, energy, water resources, forestry, human health and coastal zone management so far.

Climate change mitigation

In line with the Benin National Adaptation Programme of Action, the Government of Benin has started the promotion of renewable energies and high-performance economical homes, particularly in areas vulnerable to climate change and where lands are highly eroded (UNDP 2018).

This is also in line with the government's focus on improving the overall energy supply system, the quantity and the quality of energy sources and on enhancing the efficiency of energy supply and demand in Benin, "Strengthening the Resilience of the Energy Sector in Benin to the Impacts of Climate Change", a joint programme initiated by the Government of Benin and United Nations Development Programme, aims at enhancing the human, institutional and regulatory capacity for better planning and management of the energy resources; to increase the production, transport and distribution of the different forms of energy; and to improve poor rural access to energy. The main objective of the programme is to reduce the impacts of climate change and variability on Benin's energy sector (UNDP 2017).

Climate change adaptation

Based on the National Adaptation Programme of Action, first approaches for dealing with adaptation to climate change have been implemented in Benin for during the last few years. Priority sector-driven adaptation projects so far include, among others (UNDP 2017):

- Mobilization from surface waters in order to adapt to climate change in vulnerable areas in the centre and the North of Benin;
- Implementation of a climatic risk forecast and alert system for food security in four agro-ecological areas across the whole country area;
- Protection of the coastal area to counter the rising of sea level.

Overall then, the integration of adaptation into the agricultural sector will be crucial for reducing the vulnerability of the sector. Commissioned by GIZ, a five-year pilot project on "Adaptation of the agricultural sector to climate change in Benin" was launched in 2014 (GFA 2015).

The project intervenes in three neighbouring communities of the Pendjari National Park and the National Park W, where the impacts of climate change constitute a considerable burden on municipalities and their capacities to manage natural resources. The objective of the project is to strengthen relevant actors from governmental partner organizations, municipal authorities, the private sector, civil society and local producers in planning and adapting climate sensitive measures directed towards the sustainable management of watersheds.

However, it is apparent that adaptation to climate change has not yet been covered by a centrally located and efficient joint coordination and implementation mechanism. Many projects and initiatives still remain on a piloting level, in order to contribute to the knowledge basis of the Government of Benin for developing a clearer course of action over the mid-to long-term.

Multilateral and bilateral cooperation activities

Based on the National Adaptation Programme of Action of Benin, multilateral organizations and bilateral agencies have been working on supporting Benin's response to challenges posed by climate change.

Multilateral cooperation

United Nations Development Programme (UNDP): Among other areas of dedication, UNDP is working with the Government of Benin to ensure that a new tranche of USD 4.45 million is used to mainstream adaptation into broader development frameworks, reduce vulnerability to climate change and diversify and strengthen livelihoods and sources of incomes for vulnerable people in Benin. In this context, the "Strengthening the Resilience of Rural Livelihoods and Sub-National Government System to Climate Risks and Variability in Benin" project will work to ensure that climate change and gender are included in development plans and budgetary processes, improve agricultural infrastructure and human capacity to cope with changing rainfall patterns and diversify income-generating activities on the community level (UNDP 2017).

World Bank Group (WBG): In Benin, the World Bank particularly supports the country's poverty reduction strategy to increase growth, improve basic service access, governance and institutional capacity building. In its current project portfolio with Benin, the World Bank supports projects related to energy service improvement, agri-

cultural productivity and food health nutrition and rural and small town water supply and sanitation (World Bank 2017).

Bilateral cooperation

The Federal Republic of Germany has enjoyed excellent relations with the Republic of Benin since the West African country gained its independence in 1960.

Benin is one of the development partners with which Germany cooperates closely on the basis of intergovernmental agreements. Germany is one of Benin's main donors. At the government negotiations in September 2016, Germany pledged a total of EUR 69.9 million for development cooperation with Benin for the period 2017 to 2019. Of this, EUR 25 million was designated to financial cooperation and EUR 43 million for technical cooperation. In 2015, an additional EUR 12.9 million was made available to modernize a hydropower station and to secure funding for the Pendjari Biosphere Reserve. A further EUR 1.9 million were provided for programmes within the special initiative "One World – No Hunger".

Agreement was reached with the Government of Benin to continue working in the following priority areas of development cooperation:

- Decentralization and municipal development
- Agriculture
- Integrated water resource management, water supply and sanitation.

In addition to these priority areas, Germany is also engaged in the fields of macroeconomic advisory services, primary education and energy supply.

German Society of International Cooperation (GIZ): GIZ operates in more than 10 locations throughout Benin, with their head office being located in Cotonou. In line with German priority areas of development with Benin, GIZ focusses its work on three priority areas, i.e. a) decentralization and municipal government (good governance), b) agriculture and adaptation to climate change (including activities under the BMZ special initiative "One World – No Hunger") and c) rural/urban water supply and sanitation, including integrated management of water resources. Other fields of activity include supporting Benin's Development Ministry in implementing the national poverty reduction strategy and building the capacities of

the Ministry of Preschool and Primary Education and the education authorities to improve learning opportunities for the country's young people. GIZ participates in a regional programme to expand the West African electricity market and provides funding to supply rural areas with electricity from renewable sources under the Energising Development initiative (GIZ 2017).

German Development Bank (KfW): KfW supports Benin with regard to its water supply, rural development, education and the decentralization of administrative structures (KfW 2017).

3.4.3. Analysis of thematic focus areas

Renewable energies and energy efficiency

Energy consumption in Benin is characterized by a heavy dependency on wood and a substantially low level of access to electricity (28 % in 2012) and modern energy sources for cooking such as gas and kerosene. In 2010, the percentage of wood energy consumption, i.e. firewood and charcoal, was 77.5 % of the total energy consumption in households, while kerosene had a share of 20.3 %, electricity of 1.8 % and gas a share of 0.4 %.

In 2010, national consumption of wood was about 6.25 million tons; however, in that year there was a sustainable production of just 4.5 million tons. This has led to pressure on the supply of wood resources in the central and northern parts of the country, especially in urban areas where population growth is relatively high. Vast expenses are therefore made on common energy sources such as kerosene, petrol, candles and batteries. A household without electricity can spend an average of 20 % of its income on energy.

At the national and sub-regional level, renewable energy production is marginal or even non-existent. Yet the potential of photovoltaic solar energy is very high in Benin. In fact, sunlight is abundant and ranges between 3.9 and 6.1 kWh/m²/day.

Meteorology

In Benin, the institution in charge of meteorological services is the Agence Nationale de la Météorologie (Météo-Bénin), which plays a key role for monitoring weather and

climatic data in the country.

Concerning climate change, the main task of Météo-Bénin is to “regarder l’avenir en face” (“facing the future head on”), mainly by taking a close look at a couple of meteorological signals including temperature, dry spells and precipitation/rainfall levels (acotonou 2016). The agency publishes periodic and seasonal climate forecasts which are then disseminated through local radio stations and published by national news agencies (Adaptation Insights 2010).

Generally, it remains clear that meteorological services as a whole need to become more efficient and effective in order to contribute meaningfully to the country's response to climate change. Moreover, even though some pilot projects have been implemented over the past couple of years (e.g. UNDP has financed a project on developing a sub-regional climate risk forecast and early warning for the farming population), the meteorological sector of Benin has not yet been the subject of much discussion in the framework of Benin's climate change strategy.

Water

Among recent development successes of Benin is the country's steady and ongoing progress in improving the population's access rate to safe drinking water. By 2015, the Government of Benin had successfully achieved its target access rate of 73 %: By then, 85 % of the population in urban areas and 72 % in rural areas had access to drinking water. The same cannot be said for sanitation, however: With an access rate to sanitation services of just 36 % in urban areas (3 % in rural areas) in 2015, Benin failed to reach its 2015 target of 69 % (UNWATER 2017).

With the adoption of the National Water Policy in 2009, which was combined with Benin's Growth Strategy for Poverty Reduction, the sector has become more structured. Water supply and sanitation are identified as priority sectors within Benin's Poverty Reduction Strategy Paper. The implementation of a sector-wide approach, the adoption of clear and focussed policy and strategy documents as well as the development of multi-year investment plans for water supply have contributed to a considerable improvement in the sector (WSP 2015). However, it is clear that greater effort is still required in the sanitation sector, which should be considered a priority in the near future.

Agriculture

Agriculture is the second most important pillar of Benin's economy. It makes up one third of the GDP. Cotton is the most important export crop. However, Benin is only a minor player in the global cotton market. The country's cotton farmers have hardly any hope of competing with the large, highly subsidized producers in other countries. The sector also faces problems within Benin itself, for instance when it comes to treating and processing raw cotton.

Despite the given challenges, it is especially the agricultural sector which has potential for poverty reduction in the country. That is why the government has developed an agriculture strategy with the main goal of boosting performance in the agricultural sector. The cotton industry in particular, which is so important for Benin's economy and which has seen earnings fall over the last few years, is set to be reinforced in the future and reformed with the involvement of the private sector (BMZ 2017).

Human Health

Until the late 1980s, less than 30% of the population of Benin had access to primary health care services. Consequently, Benin had one of the highest death rates for children under the age of five in the world: Its infant mortality rate stood at 203 deaths for every 1000 live births.

The Bamako Initiative changed that dramatically by introducing a community-based health care reform, resulting in more efficient and equitable provision of services (WHO 2017). However, Benin still has one of the highest rates of maternal mortality in the world (WHO n.d.). Additionally, malaria remains a problem in Benin where it is a leading cause of morbidity and mortality among children younger than five years.

Starting from the 1990s onwards, a comprehensive approach strategy was developed and extended to all areas of health care, with subsequent improvement in the health care indicators and improvement in health care efficiency and cost. In this context, Benin's five-year health strategy for 2015–2020 is focussed on reducing preventable deaths among vulnerable populations in Benin (Malaria.com 2017). The focus of the Ministry of Health is scaling up health interventions which reduce avoidable deaths and address maternal, newborn and juvenile health challenges.

Emphasis needs to be put on the country's overall approach to dealing with the high prevalence of malaria and the subsequent high number of malaria morbidity and mortality throughout the country. In this regard, the Ministry of Health aims at combining prevention and treatment activities, including bed net distribution and social marketing; case management of simple and complicated malaria in young children; intermittent prevention of malaria in pregnant women; and improved malaria diagnosis with both microscopy and rapid diagnostic tests. Additionally, international donor funding also supports the National Malaria Control Programme in implementing reforms which improve the health commodity supply chain system.

3.4.4. Quality infrastructure services in relevant areas

Quality policy, regulation and important institutions

Until recently, Benin's quality infrastructure was regulated by several laws, empowering distinct organizations to carry out the related services in the country. In January 2017, the National Agency for Standardization, Metrology and Quality Control (Agence Nationale de Normalisation, de Metrologie et du Contrôle Qualité – ANM) was established through Decree n°2017- 031. The ANM replaces the previously established Agency for Standardization and Quality Management of Benin (Agence Béninoise de Normalisation et de Gestion de la Qualité – ABeNOR), which was created in November 2010, as well as the Metrology and Quality Control Agency of Benin (Agence Béninoise de la Métrologie et de Contrôle de la Qualité – ABMCQ), which was formed in 2015 (République du Bénin 2017a, 2010, 2015).

Altogether, the ANM is comprised of four separate departments operating in the fields of metrology, standardization, inspection and control services and the administration of the organization (Interview 1). ANM is placed under the Ministry of Industry, Commerce and Craft (République du Bénin 2017a). The organization has 75 employees, of which 37 are financed by the state and 38 are paid with the organization's own revenue. At the moment, the organization meets its expenditures mainly through its earnings from metrology services offered and to a lesser extent through the provision of standardization services (Interview 1).

Quality infrastructure status	Metrology	Standardization	Testing	Certification & inspection	Accreditation
Renewable energy					
Energy efficiency					
Meteorology					
Agriculture					
Water					
Human health					

Quality infrastructure development status	High	Medium	Low	No information
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Table 27: Development of quality infrastructure in relevant sectors

Currently, a decree on a National Quality Policy is being finalized (Interview 1). Moreover, quality issues are addressed in regulations for many sectors, including the ones treated in this study:

- The energy sector is governed by the Benin Rural Electricity and Energy Control Agency (l'Agence Béninoise d'Électrification Rurale et de Maîtrise d'Énergie – ABERME), which is placed under the Ministry of Energy and has been created by decree in 2009 to regulate rural electrification, energy control and consumption (République du Bénin 2001, 2017b, 2009).
- With regards to agriculture, a study carried out by the World Bank in 2015 suggested that the adoption of an agricultural quality strategy in line with the regional quality policy defined in the Economic Community of West African States (ECOWAS) would be recommendable. Decree n° 2017-101 recently established the Territorial Agencies of Agricultural Development (Agences Territoriales de Développement Agricole – ATDA) to promote Benin's agriculture.
- Regarding water, Decree n° 2001-094 defines the quality requirements for drinking water in Benin.

Metrology

As mentioned in the previous section, ANM is responsible for metrology in Benin (ANM 2017a). Currently, there are no secondary calibration laboratories in the country (Interview 1). ANM is a member of the West-African Metrology Secretariat (Secrétariat Ouest-Africain de Métrologie – SOAMET), and as such is a member of the Intra-Africa

Metrology System (AFRIMETS) (AFRIMETS 2017). Moreover, ANM is a corresponding member of OIML (OIML 2017) but is not yet a member of the BIPM (BIPM 2017). In the development of metrological capacities, ANM has collaborated with the national metrology institutes of Germany and Turkey. Currently, collaborations with Tunisia and South Africa are considered (Interview 1).

ANM provides metrological services for mass, temperature, pressure and volume. The mass calibration laboratory (Laboratoire d'Étalonnage des Masses – LEMA), has been accredited by the French Accreditation Committee (Comité Français d'Accréditation – COFRAC) in accordance with ISO 17025 (ANM 2017b). It is planning to also become accredited for temperature and pressure. The procedures for quality management are in place and contacts are being established to carry out intercomparison measurements. So far, however, no such measurements have taken place. Beyond this, ANM plans to develop capacities in the areas of dimensional metrology, force and pH. In legal metrology, a focus lies on the verification of tank trucks, tanks and containers (Interview 1).

For the thematic areas considered in this study, the following priorities and developments are of interest:

Energy efficiency and renewable energies

Recently, a test bench for electricity meters was installed at the electricity laboratory of ANM with the support of PTB (Interview 2). This creates a basis for future activities in the areas of energy efficiency and renewable energies.

Meteorology

In the field of meteorology, existing services in temperature are of relevance. However, no information about the use of existing services or a possible collaboration between the ANM's metrology department and the National Metrology Agency (Agence Nationale de la Météorologie – Météo-Bénin) could be retrieved.

Agriculture

The development of metrological services for the agricultural sector is viewed as a priority at the moment. Especially quality assurance for fish, cotton, cashews, shea, soy and pineapple products is crucial for the local economy (Interview 1). The existing metrological services in mass, volume, temperature and pressure, as well as the planned services for pH and force are relevant for agricultural products and their processing.

Human health

With regards to health, it is planned to provide verification of blood pressure meters. A new technical regulation is under discussion with the respective ministry (Interview 1).

Standardization

ANM's standards department is the National Standardization Body of Benin. It actively participates in standards development at the regional level within the ECOWAS Standards Harmonization Model (ECOSHAM). Moreover, it is a member of the ARSO (ARSO 2017), the Standards and Metrology Institute for Islamic Countries (SMIIC) and of the ISO. Within ISO, Benin is a participating member in the ISO/PC 305 Committee of Sustainable non-sewered sanitation systems and has observer status in the ISO/TC 34 Committee of Food Products. Benin further has observer status in the Policy Development Committee on developing country matters (ISO/DEVCO) (ISO 2017).

Over 200 national standards exist. They are published in the national standards catalogue. The majority of the national standards are of interest for the agricultural and water sectors. Eighteen standards are currently under revision. Standardization is carried out in line with harmonization efforts among the ECOWAS member countries (Interview 1). Regarding the sectors selected for this study, specific information regarding agriculture and health could be gathered:

Agriculture

As is the case for metrology, the main focus for standardization lies on agricultural primary products such as shea, cashews, pineapple and poultry farming (Interview 1). A study by the Food, Agriculture and Natural Resources Policy Analysis Network carried out in 2012 addressed standards in the area of post-harvest losses and found that several standardization challenges remain due to inadequate coordination between different actors in the creation of the necessary policy framework, in standards development itself and in the application of existing standards by industry or farmers (Anihouvi et al. 2014).

Human health

For the health sector, some standards are developed directly by the National Directorate of Public Health (Direction Nationale de la Santé Publique – DNSP) under the Ministry of Health (Interview 1).

Testing

Several bodies offer testing services in Benin. Most testing services are focussed on the agricultural sector. However, available testing services do not always deliver reliable results and only a few tests are accredited by an internationally recognized accreditation body. Currently, Benin has three accredited testing laboratories, one of which offers services for the agricultural sector, while the other two offer services for civil engineering (COFRAC 2016). Some international organizations support the accreditation of testing laboratories. However, it is difficult for laboratories to maintain and renew their accreditation without help since the laboratories do not have the necessary financial resources to cover the renewal costs of the accreditations (Osseni et al. 2015). A laboratory association or network which could support individual laboratories does not exist (Interview 1).

The National Food Safety Agency (Agence Béninoise de Sécurité Sanitaire des Aliments – ABSSA) is worth mentioning. It was established in 2012 through Decree n°2011-113 (République du Bénin 2012), has several laboratories, among which the Central Laboratory of Food Safety Control (Laboratoire Centrale de la Sécurité Sanitaire des Aliments – LCSSA) and is present throughout Benin. It is a state-funded organization with over 250 employees (Interview 1). ABSSA carries out seed and plant analyses, physical-chemical analyses, contaminant control (e.g. pesticides, DDT, heavy metals), toxin control (e.g. mycotoxins and aflatoxin), input control, food control and

market and restaurant control (see section on “Inspection” below) (République du Bénin 2012).

Additionally, private laboratories operate in specific market niches. The Regional Institute of Industrial Engineering, Biotechnology and Applied Sciences (IRGIB-Africa), for example, focusses on petroleum and food products (Interview 1).

With respect to the focus areas of the study, the following observations can be made:

- *Energy efficiency and renewable energies* are currently not a focus area for quality infrastructure in Benin. The Agency for Control of Interior Electric Installations (Agence de Contrôle des Installations Électriques Intérieures – CONTROLEC) carries out tests to ensure the safety and quality of electrical and electronic equipment. Additional capacities in these fields exist mainly at universities. It should be noted, however, that several projects are currently being developed. In the second phase of the project carried out by the Millennium Challenge Corporation of the United States, the installation of a laboratory for air conditioners and refrigerators at ANM is planned. Moreover, a laboratory to enable the development of renewable energies is considered within the framework of a collaboration project with the European Union (Interview 1).
- Several important services for the agricultural sector and for assurance of food safety are lacking or need to be improved, e.g. testing for bromate, vitamin content or heavy metals.
- Regarding the water and human health sectors, there are currently no accredited water testing laboratories in Benin. However, within the framework of an ongoing project of the GIZ (German Society for International Cooperation), the accreditation of the laboratory for drinking water analysis of the Ministry of Health is being pursued (Interview 3). The Benin National Drug Quality Control Laboratory (Laboratoire National de Contrôle de la Qualité des Médicaments – LNCQ) received equipment for high pressure liquid chromatography by USAID in February 2017 (Ahouansè 2017).

Certification and inspection

Next to ANM, the most relevant public inspection bodies are run by the following institutions:

- The National Food Safety Agency (Agence Béninoise de Sécurité Sanitaire des Aliments – ABSSA)
- The Directorate of Fishery (Direction de Pêche – DP)
- The Directorate of Hygiene and Sanitary Base (Direction de l’Hygiène et de l’Assainissement de Base – DHAB)
- The Directorate General for Trade (Direction Générale du Commerce – DGC)
- The Directorate General for Industry Development (Direction Générale du Développement Industriel – DGDI)
- The Agency of Air Navigation Security of Africa and Madagascar (Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar – ASECNA) is responsible for the analysis of air traffic, telecommunication and aviation meteorology of Western Africa and Madagascar.

Because of lacking resources, equipment and capabilities, in many cases the inspection bodies mentioned above cannot perform their missions properly and often rely on only visual inspections. This leads to a lack of faith in the reliability of the organizations and to difficulties in receiving accreditation (World Bank 2015).

ANM is defined as the national certification body of Benin. The process of preparing the organization for an accreditation is being supported as part of an ECOWAS programme. For certification, collaborations with Tunisia and Morocco are planned (Interview 1).

ABSSA and the Department of Animal Husbandry of the Ministry of Agriculture, Livestock and Fisheries test food products and issue certifications for import and export (International Trade Administration 2016).

Accreditation

Benin does not have a National Accreditation Body. Accreditation, among other things, is currently performed by the French Accreditation Body COFRAC. Collaborations with Tunisia and Morocco, especially for the accreditation of certification bodies are planned (Interview 1).

Benin is involved in the process of creating an ECOWAS accreditation system. In May 2017, a scheme was approved with the plan of establishing two organizations in the ECOWAS region responsible for accreditation: one for the Anglophone and one for the Francophone countries of the region (Interview 1).

Quality assurance in the WAEMU and ECOWAS

Benin is part of the West African Economic and Monetary Union (WAEMU, it is also known by its French acronym, UEMOA), which brings together eight West African countries. The union uses French as a working language and supports among other things quality infrastructure in the region. With regulation No. 01/2005/CM/UEMOA, the member countries defined a quality infrastructure scheme with the intention of harmonizing quality infrastructure related activities in the region. The following regional quality infrastructure institutions have been established within the WAEMU (UEMOA 2005):

- The West-African Secretariat for Metrology (Secrétariat Ouest Africain de Métrologie – SOAMET) is the association of national metrology institutes of the WAEMU and a member of the continental metrology institution AFRIMETS
- The Regional Secretariat of Standardisation, Certification and Quality Promotion (Secrétariat Régional de la Normalisation, de la Certification et de la Promotion de la Qualité – NORMCERQ) is responsible for the harmonization of standards and conformity assessment
- The West-African Accreditation System (Système Ouest Africain d'Accréditation – SOAC) is responsible for accreditation (Osseni et al. 2015).

Moreover, Benin is part of the Economic Community of West African States (ECOWAS), which brings together 15 countries in the region and fosters regional integration (ECOWAS 2017a). Quality infrastructure harmonization is also an important topic within this larger community. A regional organization tasked with the harmonization of standards already exists in the

form of the ECOWAS Standards Harmonization Model (ECOSHAM). Moreover, in April 2017, the region's Ministers of Industry signed a decree on the adoption of the West African Quality System (WASQ) within ECOWAS. The creation of the WASQ is supported by UNIDO and the European Union (Interview 2). The system will be in operation in all three regional languages (English, French and Portuguese) and is planned to comprise the following institutions:

- The Community Quality Counsel (CCQ) will advise the ECOWAS Commission on quality-related issues
- The ECOWAS Quality Agency (ECOWAQ) will be the independent executing agency which implements decisions of the CCQ
- The Regional Accreditation System (RAS) will be responsible for accreditation in the region and provide accreditation services in English and French
- The Community Conformity Assessment Committee (CCAC) will support the harmonization of services provided by national conformity assessment bodies
- The Community Committee for Metrology (CCM) shall provide the definition and implementation of a community policy on metrology, which aims to reach international levels. (ECOWAS 2017b)

However, it is still unclear how the organizations will be set up and financed. Also, the interconnections with national quality infrastructure institutes and sub-regional organizations still need to be defined (Interview 2).

The meeting of Ministers in charge of industry and agriculture of ECOWAS member states also signed an agreement on the industrial development of cashews and cocoa in April 2017. It encourages the promotion of the products' agricultural value chains through the regional quality infrastructure (ECOWAS 2017c).

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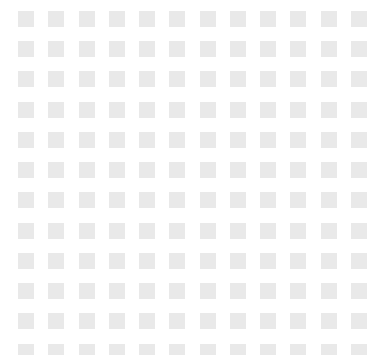
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Interviewee list

- Loukoumanou Ossen, General Director at ANM
- Florian Paffenholz, Project Coordinator at PTB
- Helga Fink, “Integrated water resource management and water supply” Program Director GIZ



Section 4 – Financial Opportunities for the Development of Quality Infrastructure

Author: Carmen Morales

Climate Financing is critical to meet climate change mitigation and adaptation challenges. In order to significantly reduce emissions, large-scale investments are required, especially in the sectors of renewable energies and energy efficiency. Furthermore, climate finance is equally important for adaptation. Significant financial resources will be similarly required to allow countries to adapt to the adverse effects and reduce the impacts of climate change. Not only climate finance but also the implementation of technical cooperation projects should contribute to overcoming the challenges of climate change mitigation and adaptation.

This chapter provides an overview of the main sources of funding for climate change related projects in Sub-Saharan Africa, considering the importance of quality infrastructure services.

4.1. Bilateral cooperation

Some information on potential German funding entities is provided in the following section. Further details on country-specific programmes financed by the German cooperation in Sub-Saharan Africa can be found in the country sections.

Federal Ministry of Economic Cooperation and Development (BMZ): In BMZ's African Policy from 2016, the focus lies on partnerships for renewable energy, climate risk insurance and forest conservation. Quality infrastructure is not mentioned directly in the documents, but the topic is of great importance for PTB's expertise on climate change mentioned in this study. Through the launch of a new Africa Renewable Energy Initiative in 2015, the African continent will move towards a massive increase in access to energy and a low-carbon development strate-

gy. BMZ's contribution for the Africa Renewable Energy Initiative in the period up to 2020 amounts to the total of USD 3 billion. Cross-border power transmission, leveraging private investment or the expansion of the Energising Development partnership are some concrete initiatives being implemented in Sub-Saharan Africa. Another strategy aims at intensifying cooperation with the German private sector. It would be useful for PTB to consider that BMZ will be working with the private sector to develop industry-specific solutions (for instance in the field of environmental technology) with support from the Green Climate Fund (BMZ 2016). For further information on application procedures for BMZ, the following website can be visited: <https://bengo.engagement-global.de/antragstellung-und-prozedere.html>.

Federal Ministry of Education and Research (BMBF):

As mentioned in the Africa Strategy 2014–2018, the groundwork for the cooperation between the Federal Ministry of Education and Research (BMBF) and its partners in Africa was laid more than thirty years ago through intergovernmental agreements on bilateral cooperation in science and technology. Research and education are the two pillars of BMBF's cooperation in Africa. In terms of the importance of focuses, environment in its many facets in the area of research is the longest standing subject of cooperation between the BMBF and Africa. Health, food security and social development are three further joint priority focus areas. The scope of projects on the environment, for example, covers many research areas which include climate change, ecosystems, water, environmental technologies, biodiversity, the protection of natural resources, earth system science, sustainability in megacities and many others.

Some relevant examples for projects on the environment are the following: BMBF has established a Regional Science Service Centre for Climate Change and Adapted Land Management in Africa to work together with 15 African partner countries. The BMBF aims at investing €120

million in the establishment and operation of such centres in West Africa (WASCAL) and Southern Africa (SASSCAL). The training of young scientists from African countries is one of the most critical tasks (BMBF 2017). In the areas of environment, health and bio economy, there are some areas where quality infrastructure services could potentially play an important role.

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB): Two initiatives within BMUB could be potentially interesting for the financing of PTB's projects in Sub-Saharan Africa.

- **BMUB's – "Environmental Technologies Export Initiative":** Topics being covered by this initiative are (water and wastewater management, recycling management as well as waste and raw materials management, resource efficiency, wastewater and soil treatment, sustainable or energy-saving building and urban development, sustainable consumption, environmentally friendly mobility and air pollution control).

It needs to be clarified whether PTB is an institution with a legal status to submit applications to this initiative. The project budget ranges from 20,000–400,000 € and some projects have been implemented in Sub-Saharan countries like Kenya and South Africa. For further information, the website can be visited at: <http://www.bmub.bund.de/themen/wirtschaft-produkte-ressourcen-tourismus/wirtschaft-und-umwelt/umwelttechnologien/exportinitiative/> (BMUB 2017).

- **BMUB International Climate Initiative (IKI)** has been financing climate and biodiversity projects in developing and newly industrialising countries, as well as in countries in transition. Funds have been made available through the Special Energy and Climate Fund to ensure the financial continuity of the programme. Both funding mechanisms are now part of the Federal Environment Ministry's regular budget. The IKI funds projects in the following areas (mitigating greenhouse gas emissions, adapting to the impacts of climate change, conserving natural carbon sinks with a focus on reducing emissions from deforestation and forest degradation (REDD+) and conserving biological diversity).

For the IKI, it must also be clarified as well whether PTB may send proposals for financing their projects and if they may access the funds working in consortia with other organizations. The project budget ranges from 300,000–65,000,000 € and cover most of the topics addressed in this study. There are 143 IKI-funded projects in Sub-Saharan Africa (IKI 2017).

4.2. Multilateral cooperation

Some insights of potentially interesting multilateral funding entities are provided in the following table.

Source of funding		Accredited countries	Relevant sectors covered in Sub-Saharan Africa	Funding range of sector-related projects
Adaptation Fund (AF)		Ethiopia: accredited Kenya and Benin: re-accreditation in progress	Water Agriculture	around 7–10 Mio USD
Green Climate Fund (GCF)		Ethiopia and Kenya: accredited	Meteorology Renewable energies	around 45–110 Mio USD
Global Environment Facility (GEF)		Political and operational focal points in Ethiopia, Kenya, Uganda and Benin	Renewable energies Water Agriculture	around 1–12 Mio USD
Climate Investments Funds (CIF)	Pilot Program for Climate Resilience (PPCR)	Government Focal Point in Ethiopia and Uganda	Agriculture Water Meteorology	Information not found
	Scaling Up Renewable Energy in Low Income Countries Program (SREP)	Government Focal Points existing in Benin, Ethiopia, Kenya and Uganda	Renewable energies	around 1–25 Mio USD

Table 28: Main multilateral funding entities active in Sub-Saharan Africa, including their relevance for quality infrastructure.

Adaptation Fund (AF): The Adaptation Fund (AF) was established in 2010 with the goal of financing concrete adaptation projects and programmes in developing countries particularly vulnerable to the adverse effects of climate change. Since then, the AF has committed USD 418 million for the support of 67 countries. The fund finances climate adaptation projects in sectors such as agriculture, disaster risk reduction, food security, forests, rural development, urban development and water management. Current ongoing projects in the countries treated in this study which are funded by the AF are both of regional (Kenya, Uganda and Ethiopia) and of national character. The main thematic areas cover multi-sectoral, agriculture and water management topics.

Implementing entities are the national, regional and multilateral institutions accredited by the Adaptation Fund Board which receive direct financial transfers from the Fund in order to carry out adaptation projects and programmes. On the one hand, accredited multilateral implementing entities which might be of interest in the context of this study are UNDP, United Nations Environment Programme (UNEP), WFP and WMO. On the other hand, national implementing entities in countries treated in this study which are suitable for cooperation in quality infrastructure relevant areas are the Ministry of Finance and Economic Cooperation of the Federal Democratic Republic of Ethiopia, the National Environment and Climate Fund in Benin and the National Environment Management Authority in Kenya.

Projects funded by the AF in the four pilot countries correspond to the sectors analysed in this study, especially the agriculture and the water sectors. Quality infrastructure services with potential to support adaptation activities should be integrated in these kinds of projects. In order to achieve this, partnerships or consortiums of national or regional quality infrastructure institutions with national or multilateral implementing institutions should be fostered.

Green Climate Fund (GCF): The Green Climate Fund (GCF) became fully operational in 2015 and is the newest actor in the multilateral climate finance architecture. Since then, the GCF has funded 43 projects with beneficiaries all over the world, most of which are in Africa. The Fund aims at promoting a paradigm shift towards low-emission and climate-resilient development pathways by providing support to developing countries to limit or reduce

their greenhouse gas emissions and to adapt to the impacts of climate change, taking into account the needs of those developing countries particularly vulnerable to the adverse effects of climate change. Roughly 41% of the projects are relevant in the mitigation context, 27% in the adaptation context and 32% cover cross-cutting projects.

To give an example, one project funded by the GCF located in Malawi aims at expanding the meteorological network and installing automatic weather stations and hydrological monitoring stations. In this context, quality infrastructure services are of crucial importance and highly demanded by relevant government entities in the region (see section 2.3 on meteorology). Some other projects of regional scale in Benin and Kenya are focussed on renewable energies.

The Green Climate Fund works through a wide range of accredited entities to channel its resources to projects and programmes. Among German accredited entities are the GIZ and the KfW. Other entities located at the international level are FAO, IFAD, UNDP, UNEP, WFP and WMO. National accredited entities also exist in Kenya (National Environment Management Authority of Kenya) and Ethiopia (Ministry of Finance and Economic Cooperation of the Federal Democratic Republic of Ethiopia).

It appears clear that quality infrastructure services might be demanded in projects funded by the Green Climate Fund (for example, for the meteorology project in Malawi). For this reason, accessing resources of the Green Climate Fund to undertake climate change projects in Sub-Saharan African countries should be considered. This could be done either in partnership with currently accredited entities or by applying for accreditation. The first step would be to identify the minimum requirements which an institution must meet before it can be accredited to receive funding from the Green Climate Fund. This can be easily done through the Green Climate Fund accreditation self-assessment tool (see <http://www.greenclimate.fund/partners/accredited-entities/self-assessment-tool>).

Global Environment Facility (GEF): Funds provided through the Global Environment Facility are available for developing countries to meet the objectives of international environmental conventions and agreements. In the context of the study presented here, the Global Environment Facility Trust Fund appears especially important from a thematic perspective. Funded by the Special

Climate Change Fund or the Least Developing Countries Fund, some projects in the four countries covered by the study presented here are currently being implemented, while generally most of the projects are funded through the Trust Fund.

Land degradation, forest management and carbon stocking, waste management as well as renewable energies in the context of climate change adaptation and mitigation are topics covered by current projects being implemented in the four countries covered in the study presented here. Agencies executing and managing GEF-funded projects in these countries are UNDP, UNIDO, UNEP, FAO and IFAD. All of the four countries have political and operational focal points located in relevant ministries.

Quality infrastructure services might be demanded due to the topics covered by the funded projects. Partnerships with executing agencies could be considered in order to channel the funding of the Global Environment Facility.

Climate Investment Fund (CIF): The Climate Investment Fund (CIF) provides developing countries with resources to manage the challenges of climate change and to reduce their greenhouse gas emissions. Since 2008, CIF has supported efforts to empower transformations and foster resilience in the energy, transport and forestry sectors. Germany provides comparatively large financial contributions to CIF, after the US, UK and Japan. At least two interregional programmes financed by the Climate Investment Fund are relevant in the context of this study: the Pilot Program for Climate Resilience (PPCR) and the Scaling Up Renewable Energy in Low Income Countries Program (SREP).

PPCR was approved in November 2008 with initial funding of USD 1.2 billion for helping developing countries integrate climate resilience into development planning. The pilot program offers additional funding to support public and private sector investments for its implementation. Ethiopia and Uganda are nominated for funding a range of investment projects in the agricultural, water and meteorology sectors. SREP was approved in May 2009 with an initial funding of US\$ 780 million to support the distribution of renewable energy solutions for increased energy access and economic growth in the world's poorest countries. SREP seeks to create new economic opportunities and increase energy access through the production and use of renewable energy. In Benin and Uganda, in-

vestment plans are being constructed to scale up the development of renewable energies. Ethiopia and Kenya are already implementing renewables projects in rural areas, with a specific focus on geothermal development.

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Section 5 – Conclusions

Authors: Katharina Telfser, Dennis Eucker, Niels Ferdinand

5.1. General conclusions

Adaptation to climate change is fundamental for the sustainable and socioeconomic development of the countries of Sub-Saharan Africa

Sub-Saharan Africa is one of the least greenhouse gas-emitting regions in the world, so that mitigation measures have not been ranking high on the political agenda so far. However, due to high exposure to climate hazards, the population's high sensitivity and limited adaptive capacity, Sub-Saharan Africa faces a multitude of risks related to climate change. Considering this, taking systematic and comprehensive approaches for adaptation to climate change is fundamental for the future socioeconomic development of the countries and contributes to the achievement of the SDGs.

Quality infrastructure is a key element for effective and efficient climate change mitigation and adaptation

Quality infrastructure services – in accordance with international standards and best practices – are essential for achieving sustained success in key areas of climate change mitigation and adaptation to climate change. These services are required to ensure product quality as well as process and system efficiency. This contribution is increasingly important, as climate change in Sub-Saharan Africa will require the improvement of well-known deficiencies in many sectors. These deficits range from lacking quality assurance in the health sector to inefficient practices in the agricultural sector or the insufficient reliability of weather forecasts, resulting in increasing risks for the population in changing climatic conditions. At the same time, quality infrastructure services are needed to generate reliable information for the monitoring of climate change and its effects in relevant sectors, thus creating the basis for decision-making and the definition of appropriate adaptation measures. Finally, quality infrastructure services are needed in Sub-Saharan African countries in order to facilitate regional and international trade of services and products.

An increased exchange of products and services can be seen as an important mitigation and adaptation measure, since it provides a necessary basis for economic development alongside other benefits such as: better adaptation of agricultural production to specific climatic conditions in the region; provision of climate-relevant testing services across borders; and trading of renewable energy system components as well as energy efficient products.

Links between quality infrastructure services and climate change have not been identified systematically or developed holistically

To date, the approach to developing quality infrastructure for climate change mitigation and adaptation has not been systematic.

Globally, some components of quality infrastructure have already developed specific services related to climate change. For example, international standards exist on greenhouse gas management, climate-friendly technologies and adaptation measures. In many cases, these services are not currently offered in countries in Sub-Saharan Africa. For example, the adoption of relevant international standards is lacking and specific accreditation services are not being offered yet. For Sub-Saharan Africa, internationally existing quality infrastructure services should therefore be identified and adapted to the specific regional and national conditions if necessary, and their application should be promoted.

For some areas, a systematic identification and development of quality infrastructure services required in the context of climate change is still lacking, even on a global level. This is true, for example, of meteorology, where quality infrastructure services are not being used systematically at present. In these areas, new quality infrastructure services should be developed and piloted according to the specific needs in the context of climate change in Sub-Saharan Africa.

Both the implementation of quality infrastructure services existing internationally as well the systematic development of new quality infrastructure services in Sub-Saharan Africa require a holistic approach. Quality infrastruc-

ture can only contribute fully to climate change mitigation and adaptation if developed as a whole as the components depend on each other. The specific demand for quality infrastructure services has to be identified along the entire value chains of relevant sectors. In a next step, the quality challenges related to climate change have to be tackled in cooperation between sector stakeholders and the organizations of quality infrastructure.

Currently, the relevance of quality infrastructure services in the context of climate change is neither sufficiently considered on the political level, nor by the private sector and by the quality infrastructure organizations themselves. For this reason, activities to raise awareness and foster the cooperation between the relevant actors are of fundamental importance.

Important opportunities for bilateral and regional projects exist

Climate change ranks high on the political agenda in Sub-Saharan Africa. At the same time, the improvement of quality infrastructure services needed for mitigation and adaptation measures is barely covered by other implementing agencies active in Sub-Saharan Africa at present. Related projects would contribute to national strategies as well as to the achievement of the SDGs.

The study identifies several funding opportunities for such projects, both on national and on regional levels. For bilateral projects, relevant sectors for climate change mitigation or adaptation were identified in the country studies, highlighting the need for further development of quality infrastructure services. On a regional level, a systematic analysis of the current and future needs as well as quality infrastructure services offered should be carried out. The further development of the offered services should be coordinated by the regional and sub-regional quality infrastructure networks in Sub-Saharan Africa, which could be supported by PTB in regional projects.

5.2. Conclusions of the thematic focus areas considered in the study

Climate change mitigation

Renewable Energies

Quality infrastructure services are especially relevant in the increasingly important sectors of photovoltaic, solar thermal and hydropower installations. Especially in the emerging photovoltaic sector, quality and safety issues may lead to a loss of reputation and decreasing interest of investors. In all sectors, the inclusion of quality criteria in tendering documents is fundamental. Reliable calibration and testing services at the national level are required to confirm compliance of installations with such criteria. Some of the international standards, like the testing specifications for photovoltaic modules, have to be adapted to the specific conditions in Sub-Saharan Africa, i.e. considering local climatic conditions, and complemented by guidance documents on aspects such as installation, maintenance and transport. Certification is required for products and components (to be implemented depending on their country of origin). Additionally, national certification schemes are mainly required for technicians involved in planning, installation and maintenance.

Energy Efficiency

Quality infrastructure is mainly relevant for the market surveillance, installation and maintenance of energy efficient refrigeration and air-conditioning appliances in Sub-Saharan Africa. The demand for such services will probably increase in the near future, as more countries in the region define energy efficiency policies, regulations and labelling systems. At the national level, personnel certification and the recognition of product certification schemes in the country of origin are required. The need for calibration and testing services could be covered by identifying the demand and services offered in the regional and sub-regional quality infrastructure networks and by coordinating the development of specialized laboratories on the regional scale.

Climate change adaptation

Meteorology

Quality management measures of the organizations related to the World Meteorology Organization are mainly implemented internally, without the use of external quality infrastructure services. In Sub-Saharan Africa, important opportunities for cooperation between the organizations of the quality infrastructure and the meteorology sector exist, especially in the areas of the calibration of equipment and intercomparisons, the certification of personnel and the accreditation of laboratories. In this context, the Regional Instrument Centres in Nairobi (Kenya) and Gaborone (Botswana) play a key role in the provision of meteorological services, as they serve as calibration laboratories for National Meteorological Services in the respective sub-regions. Cooperation activities with these centres could serve as important pilot projects for improving quality assurance in meteorology as a whole.

Agriculture

Given the importance of the agricultural sector for the economy, livelihoods and food security in Sub-Saharan Africa, the adaptation of the agricultural sector to climate change is a key element for sustainable development. Quality infrastructure services are required for an efficient use of increasingly scarce resources such as soil, nutrients and water. Moreover, they are needed for an effective quality control and for regional trade of agricultural inputs and products, which become increasingly important as climatic conditions change. In many countries of Sub-Saharan Africa, basic quality infrastructure services needed in the agricultural sector are available, such as calibrations in mass and volume or certifications of good agricultural practice. These services must be improved and expanded to fulfil the requirements of the sector for its adaptation to climate change. Services which are especially relevant in this context include metrological services for moisture and humidity, standards for agricultural inputs, guidance documents on adapted agricultural practices as well as the accreditation of testing laboratories for soil and agricultural inputs.

Water

Access to drinking water is an important topic on the political agenda in many countries of Sub-Saharan Africa. Water scarcity hampers socioeconomic development and is a fundamental issue especially for the poorer part

of the population. Challenges which are already prevalent will increase with climate change. Awareness and information on the importance of quality infrastructure for the assurance of water quality and its efficient use is lacking in most countries. Cooperation activities are needed especially in the areas of accreditation of water testing laboratories and certification of water management systems. Additionally, metrology services are required for instance for water flow meters and in chemical metrology. For both areas, advanced national metrology institutes already exist. The further development of these services could be coordinated by the regional and sub-regional metrology networks.

Human health

The effects of climate change will lead to an increased burden of disease for the population in Sub-Saharan Africa. At the same time, extreme weather events can also adversely affect the ability of institutions and organizations of the health system to maintain their services (for example due to flooding). To effectively protect human health and contribute to the SDGs in times of climate change, the health sector needs to adapt its services, products, systems and processes. Quality infrastructure provides the services required for systematic quality management to effectively and efficiently implement these adaptations. This is particularly important in the areas of medical testing, market surveillance of medication and health reporting. Metrological services are especially required for the calibration of equipment in testing laboratories. Testing services should be accredited by internationally recognized accreditation bodies, considering their relevance for the protection of human health in the context of climate change and to permit a regional exchange of testing services. Where needed, international standards should be adapted and regional or national standards and guidance documents should be created, considering the specific conditions in Sub-Saharan Africa (e.g. environmental conditions, relevant diseases, particularities of the health system). Furthermore, the inclusion of quality criteria in policies, programmes and regulations must be promoted to foster improved quality in the sector.

5.3. Conclusions of the country studies

Kenya

Climate change adaptation is considered a priority and on the political agenda of Kenya. The country appears to be a relevant and suitable cooperation partner for designing and implementing projects related to quality infrastructure for responding to climate change. The agricultural sector seems to be especially relevant for such projects. The sector is the economic backbone of Kenya and is considered to be most severely affected by climate change. Basic quality infrastructure services needed by the sector in the context of climate change are already offered and could be further improved and expanded. Additionally, agriculture is a priority sector in Kenya for the BMZ. Close linkages exist between the agricultural and the water and meteorology sectors. For this reason, it might be worthwhile to evaluate possible joint approaches.

Ethiopia

In Ethiopia, opportunities for collaboration on quality in the context of climate change stand out in the agricultural and water sectors. The respective ministries have recently launched strategies for climate resilient development, in response to the high exposure to climate change related risks in the sectors. The systematic inclusion of quality aspects and the development of relevant quality infrastructure services in line with specific needs of the sectors could contribute to a more efficient and effective implementation of climate change adaptation measures. Moreover, a focus on climate change adaptation in agriculture and water would lend itself to a follow-up project to the currently running project on the enhancement of quality infrastructure services for innovation for agriculture and food. Relevant services for the meteorological sector could be supported to ensure the provision of high-quality weather information for the agriculture and water sectors.

Uganda

The forecasted impacts of climate change are taken very seriously in Uganda. An institutional framework has been built during the past years and relevant policies and strategies are in place. Creating awareness about the relevance of quality infrastructure and fostering cooperation between the Climate Change Department, which acts as the coordinating body, the respective ministries and the organizations of quality infrastructure can be seen as an

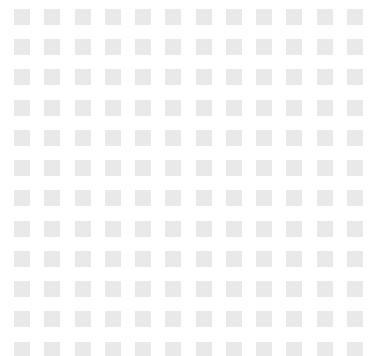
entry point for supporting the development of the needed quality infrastructure services in relevant sectors. A focus on the agricultural sector appears promising, given the importance of the sector for large parts of the population and its vulnerability to climate change with impacts already becoming visible. Opportunities also exist to strengthen the water and renewable energy sectors. Thus, a project supporting quality infrastructure for adaptation to climate change in multiple sectors could be of interest.

Benin

A clear focus is put on the agricultural sector in the overall socioeconomic development strategy and climate change policy of Benin. Hence, a collaboration for strengthening quality infrastructure services should support sustainable agriculture and economic growth and be in line with the country's climate change targets. Given Benin's important role as transit country which is highly dependent on market dynamics in its neighbouring countries, a strong regional perspective for fostering quality infrastructure development should be taken. Relevant quality infrastructure services for climate change mitigation and adaptation to climate change could be supported in the planned follow-up project with the Economic Community of West African States (ECOWAS). Moreover, a triangular cooperation project could be considered in collaboration with a country in the region with relevant quality infrastructure services in place (e.g. Tunisia).



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Annex 1

(Section 2.2. Energy efficiency): The global warming potential of refrigerants used in refrigeration and air-conditioning equipment

Historically, chlorofluorocarbon (CFC) was a common type of refrigerant in most cooling systems, but it was responsible for the depletion of the ozone layer. The 1987 Montreal Protocol required the phase-out of CFCs, which led to several manufacturers introducing HCFCs and hydrofluorocarbons (HFCs) as substitutes for either charging new appliances or newly installed systems, or for replenishing the refrigerant in existing systems. In 2007, an adjustment to the Montreal Protocol was agreed upon to accelerate the phase-out of HCFCs in both developing and developed countries. The default replacement of HCFCs in most refrigeration equipment became HFCs, which on average have a higher global warming potential and could therefore increase greenhouse gas emissions from this sector if directly substituted, leading to intensified climate impacts arising from the emissions (GIZ 2011). As a result, in 2011 a typical household refrigerator used HFC-134a in the refrigeration circuit (as well as HFC-141b as blowing agent in the polyurethane foam insulation). **This means the current stock in Sub-Saharan Africa is still dominated by refrigerants with high global warming potential.**

In 2016, the Kigali Amendment was adopted by the parties to the Montreal Protocol, under which countries have agreed to phase down their consumption and production of HFCs, which is predicted to help the world avoid up to 0.5°C of global warming by the end of the century. Although the carbon footprint of cooling is growing at a rate which is at least three times faster than the global average increase of greenhouse gas emissions, its impact can be minimized by green cooling technologies. They combine maximized energy efficiency with the use of natural refrigerants. Today, already half of all refrigerators produced globally use substitutes with marginal or no global warming potential such as the natural refrigerants CO₂, ammonia (NH₃) and hydrocarbons (HCs) such as propane and isobutane. Natural refrigerants are already widely used in some of the refrigeration and air-conditioning sub-sectors, such as domestic refrigeration (HCs) and industrial refrigeration (ammonia). However, not every natural refrigerant is suitable for every refrigeration and air-conditioning

sub-sector. For some applications, there are safety restrictions on the use of natural refrigerants (flammability of HC, higher toxicity of ammonia). In other cases, they are not compatible with current systems and technical changes would have to be made (GCI 2015).

The refrigerants in split air-conditioning appliances are mainly HCFC-22 in developing countries or R410A (an HC mixture) for developed countries. For new units, developed countries have fully phased out HCFCs and developing countries are progressing with the phase-out of HCFC for newly produced units (GCI 2015).

Conversion to systems using HCs as refrigerants and foam-blowing agents is not addressed in the energy efficiency-section, since it is not (yet) a strong market trend in Sub-Saharan Africa and for the small production volume of refrigeration and air-conditioning appliances in Sub-Saharan Africa. However, the interesting case study about the conversion to HC refrigerants of Palfridge's factory in Swaziland (GIZ 2011) should not go unmentioned here. It also includes aspects relevant to quality infrastructure.

Annex 2

(Section 2.2. Energy efficiency): Standards for reducing cooling demand by planning and design of buildings

It is also possible to reduce the cooling demand of a building or space through changes in planning and design. E.g., by preventing a heat load to build up in a space, a lot of costs and energy can be saved as smaller or no refrigeration and air-conditioning units have to be purchased and the run times can be reduced. Both direct and indirect emissions are reduced if smaller systems are used. The reduction of energy demand for heating and cooling which can be achieved through renovations and energy efficient building design is estimated to be up to 46% (bigEE 2012a).

Already at the building design stage subsequent cooling need can be reduced using passive options for building design which adapt to the climate of a region in order to maintain comfort conditions in the space. Such passive options are siting and orientation, building envelope, vegetation to protect walls and windows from direct solar radiation and natural ventilation.

With regards to air-conditioning, the adoption of the above-mentioned practices will appreciably reduce the thermal load of the air-conditioning system.

For most of these options a number of standards already exists, e.g. at ISO and European Committee for Standardization (CEN) level. The respective ISO Technical Committee has already published 25 individual standards (with 18 more tasks on their work programme (see <https://www.iso.org/committee/54740.html>). They take account of most of the above-mentioned factors and can therefore serve their intended purpose in Sub-Saharan Africa. The ISO standards must be achievable in all climates. CEN, the European Committee for Standardization, has elaborated an even higher number of standards to support the implementation of the European Union directive (see <https://www.cen.eu/work/areas/construction/buildingsenergyperf/Pages/default.aspx>) on the energy performance of buildings.

In 2011, South Africa published its first standard on energy efficiency in buildings, which focusses on the above-mentioned elements and is probably even better suited as a

starting point for other Sub-Saharan African countries (<https://store.sabs.co.za/catalogsearch/result/?q=SANS+204>).

However, building planning and design are complex issues. Many Sub-Saharan African countries will – unlike South Africa – probably not have the resources to elaborate their own national standards. Therefore, either ARSO could investigate whether to put the issue on its agenda or the regional organizations of economic cooperation or regional standardization partnerships in Sub-Saharan Africa could do so. The existing ISO, CEN and South African standards could serve as starting point.

Buildings certified to such a standard could achieve higher prices in sale or rent and pull the market upwards. They should be marketed as a life-style product to the emerging middle class.

A building standard could be referenced in the national building code making it mandatory (as in South Africa) to take the crucial issues of siting, orientation, shading and passive ventilation into account.

Annex 3

(Section 2.6. Human health): Demographic, economic, development and health estimates for Sub-Saharan Africa

Demographic estimates [2013]						
SSA Country	Population	Population growth rate	Population living in urban areas	Population under five	Population aged 65 or older	
Botswana	2 mio	2.0 %	56.9 %	11.8 %	3.5 %	
Ethiopia	95 mio	2.5 %	18.6 %	15.1 %	3.4 %	
Kenya	44 mio	2.7 %	24.8 %	16.0 %	2.7 %	
Ghana	26 mio	2.4 %	52.7 %	14.8 %	3.5 %	
Madagascar	23 mio	2.8 %	33.8 %	15.7 %	2.8 %	
Nigeria	173 mio	2.7 %	46.1 %	17.3 %	2.8 %	
South Africa	53 mio	1.1 %	63.8 %	10.4 %	5.0 %	
Tanzania	50 mio	3.2 %	30.2 %	17.7 %	3.2 %	
Uganda	37 mio	3.3 %	15.4 %	19.0 %	2.5 %	

Own compilation based on data from WHO & UNFCCC Country Profiles (2015, 2016). SSA = Sub-Saharan Africa. CC = Climate change.

Table 29: Demographic, economic, development and health estimates for Sub-Saharan Africa

Sub-Saharan African Country	Increase of vector-borne diseases	Population at risk of malaria by 2070	Mean relative vector capacity for dengue fever transmission towards 2070 (compared to 1961–1990)	Increase of water-borne diseases due to flooding	Increased proportion of diarrhoeal deaths in children attributable by 2050	
Botswana	x	120 000	0.52 (0.45)			
Ethiopia	x	130 mio	0.57 (0.44)	x	14.1 %	
Kenya	x	83 mio	0.68 (0.59)	x		
Ghana	x	58 mio	0.80 (0.73)	x	14.4 %	
Madagascar	x	46 mio	0.83 (0.53)	x	12.3 %	
Nigeria	x	400 mio	NA	x	14.2 %	
South Africa	x	300 000	0.35 (0.26)	x	14.8 %	
Tanzania	x	114 mio	0.67 (0.51)	x	13.4 %	
Uganda	x	108 mio	0.69 (0.53)	x		

Own compilation based on data from WHO & UNFCCC Country Profiles (2015, 2016).

Table 30: Projected adverse health effects due to climate change in Sub-Saharan Africa

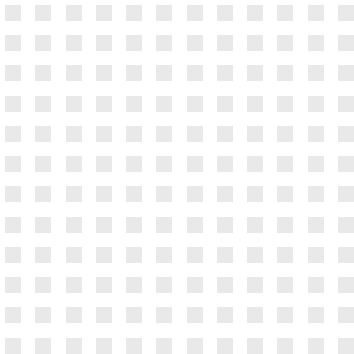
Economic and development indicators [2013]					Health estimates [2013]		
GDP per capita (current USD)	Total expenditure on health as % of GDP	Percentage share of income for lowest 20 % of population	HDI		Life expectancy at birth (years)	Under-5 mortality per 1000 live births	Prevalence of child malnutrition under age 5 [2014]
6882	5.4 %	NA	0.682^		64	47	31.4 %
503	5.1 %	8.0 %	0.435^		65	65	25.2 %
1257	4.5 %	NA	0.535^		61	53	35.2 %
1857	5.4 %	NA	0.573^		63	67	13.4 %
463	4.2 %	6.5 %	0.498^		64	53	49.2 %
2980	3.9 %	5.4 %	0.504^		55	117	31.0 %
6890	8.9 %	NA	0.658^		60	43	23.9 %
927	7.3 %	7.4 %	0.488^		63	53	13.0 %
674	9.8 %	5.8 %	0.484^		59	60	34.2 %

Food and nutritional and water insecurity	Increase in heat-related deaths in elderly (65+ years) per 100 000 by 2080 (compared to baseline between 1961–1990)	Increased mortality from respiratory infections due to outdoor air pollution	Displaced population due to flooding
	136 (3)	x	
x	65 (3)	x	x
x	45 (2)	x	x
x	70 (2)	x	x
x	50 (1)	x	x
x	80 (3)	x	
x	116 (2)	x	
x	38 (2)	x	
x	8 (2)	x	

Sub-Saharan African Country	Special programmes	National Health Adaptation Strategy	
Botswana		X	
Ethiopia		X	
Kenya	Malaria Early Warning System	X	
Ghana		X	
Madagascar	Project Climate Health*	X	
Nigeria		X	
South Africa	Adaptation Scenarios Flagship**	X	
Tanzania		X	
Uganda		X	
Own compilation based on data from WHO & UNFCCC Country Profiles (2015, 2016). *In partnership with WMO. **Long-term research programme to develop adaptation strategies.			

Table 31: Health-related climate change mitigation and adaptation measures in Sub-Saharan Africa

	National Assessment of Climate Change Impacts	Implementation of projects on climate change and health	Actions to build institutional and technical capacities to work on climate change and health
	x	x	x
	x	x	x
		x	x
	x	x	x
		x	
			x
		x	x



Annex 4

(Section 2.6. Human health): Entry points for climate change mitigation in health settings

Climate change has adverse health effects and is about to slow, halt or reverse the progress which the global public health community is making against many of the same diseases, disproportionately impacting on the most vulnerable, including children, elderly and the medically infirm. Health facilities and medical laboratories are energy- and resource-intensive enterprises which contribute substantially to climate change while inadvertently contributing to respiratory and other illnesses and thereby also to national health expenses. The health sector can play a pivotal role in adapting to these effects by limiting its own climate footprint. Procurement, resource use, computers, transport and other policies and practices contribute to the sector's significant footprint. By reducing this footprint and moving toward carbon neutrality, the health sector can play a leadership role in mitigation, contributing to public health. There are basic steps the health sector can take – from improving hospital, medical laboratory and medical device design to reducing and sustainably managing waste, using safer chemicals, sustainably using resources such as water and energy and purchasing environmentally-friendly products. The WHO & HCWH (2008) report lists seven elements of a climate-friendly health sector which takes a role in environmental stewardship:

Energy efficiency: Reduce hospital energy consumption and costs through efficiency and conservation measures, e.g. through combined heat and power (CHP) technology.

Green building design: Build hospitals which are responsive to local climate conditions and made from regional material, sited near transport routes and optimized for reduced energy and resource demands, e.g. through the Green Health Guide for Health Care.

Alternative energy options: Produce and/or consume clean, renewable energy onsite to ensure reliable and resilient operation and less vulnerability to disruptions. In Tanzania, Rwanda and Liberia, photovoltaic systems are installed in order to provide energy in rural clinics for lighting, refrigeration of vaccines and power for computers where grid electricity lacks.

Transportation: Use alternative fuels for hospital vehicle fleets; encourage walking and cycling to the facility; promote staff, patient and community use of public transport; site health-care buildings to minimize the need for staff and patient transportation.

Food: Provide sustainably grown local food for staff and patients and prevent wasting food.

Waste: Reduce, re-use, recycle and compost; employ alternatives to waste incineration.

Water: Conserve water; avoid bottled water when safe alternatives exist.

A climate-friendly health sector promotes health (reduction of global warming gases such as carbon dioxide and pollutants which increase the environmental disease burden and cardiovascular and respiratory diseases), being economic (fossil fuel is costly; conservation, efficiency and alternative energy have long-term financial benefits) and social welfare (health staff as important agents for change in communities) are co-benefits which improve the people's health on top of the traditional delivery of care.

Short Descriptions of the Authors

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Executive Summary

Human interference with the climate system is occurring; climate change poses risks to people, ecosystems and infrastructures worldwide, especially in developing countries. Thus, climate change is considered one of the central challenges of the 21st century. The Intergovernmental Panel on Climate Change (IPCC), in its Fifth Assessment Report (2014), estimates an average increase in global temperature of between 1.5° and 4.0° Celsius before the end of this century. For Sub-Saharan Africa, increasing temperatures and changes in precipitation patterns are likely to trigger severe consequences. Climate change will negatively affect different sectors, including agriculture, water supply and human health.

Climate change mitigation and adaptation to climate change are two central approaches which can reduce and manage climate change impacts and risks. For both mitigation and adaptation, quality infrastructure services can play a crucial role for ensuring lasting success over time. Additionally, quality infrastructure services are needed to generate reliable information for the monitoring of climate change, thus creating the basis for decision making and for defining appropriate adaptation measures.

The study presented here identifies the needs for quality infrastructure services in times of climate change for six selected sectors across mitigation and adaptation:

■ **Climate change mitigation:**

- a) renewable energies; and
- b) energy efficiency.

■ **Adaptation to climate change:**

- c) meteorology;
- d) agriculture;
- e) water; and
- f) human health.

Sub-Saharan Africa is a relevant and important region in the context of quality infrastructure for climate change mitigation and adaptation: While it is one of the least greenhouse gas-emitting regions in the world, meaning that mitigation measures have not ranked high on the political agenda so far, the region faces a multitude of risks

because of climate change. In view of this, taking systematic and comprehensive approaches for both mitigation and adaptation is fundamental for the future socioeconomic development of Sub-Saharan African countries and contributes to the achievement of the Sustainable Development Goals.

Against this background, the objective of the study presented here is to analyse the contribution and significance of quality infrastructure in Sub-Saharan Africa for both climate change mitigation and adaptation to climate change. After a general overview of the region in terms of the existing demand for quality infrastructure, the study takes a closer look at the status quo of existing quality infrastructure services in four selected country studies: i) Kenya; ii) Ethiopia; iii) Uganda; and iv) Benin.

After an in-depth analysis of selected sectors and countries, the study draws on a number of key findings and final conclusions. These key findings are as follows:

1. Adaptation to climate change is fundamental for sustainable socioeconomic development in Sub-Saharan Africa.
2. Quality infrastructure is essential for effective and efficient adaptation to climate change.
3. Links between quality infrastructure services and climate change have not yet been identified systematically or developed holistically.
4. Important opportunities for bilateral and regional projects exist.

In terms of sector studies included in the study, the following general conclusions can be drawn:

- a. For renewable energies, quality infrastructure services are relevant in the increasingly important sectors of photovoltaic, solar thermal and hydropower installations. Especially in the emerging photovoltaic sector, quality and safety issues may lead to a loss in reputation and decreasing investor interest.
- b. Concerning energy efficiency, quality infrastructure is mainly relevant for the market surveillance, installation

and maintenance of energy efficient refrigeration and air-conditioning appliances in Sub-Saharan Africa. The demand for such services will probably increase in the near future, as more countries in the region define energy efficiency policies, regulations and labelling systems.

- c. Concerning meteorology, quality management measures of the organizations related to the World Meteorology Organization are mainly implemented internally, without the use of external quality infrastructure services. In Sub-Saharan Africa, important opportunities for cooperation between quality infrastructure and meteorology sector organizations exist, especially in equipment calibration and intercomparison, personnel certification and laboratory accreditation.
- d. In agriculture, given the importance of the sector for the national economies, livelihoods and food security in Sub-Saharan Africa, the adaptation of the agricultural sector to climate change is a key element of sustainable development. Quality infrastructure services are required for the efficient use of increasingly scarce resources such as soil, nutrients and water. Moreover, such services are needed for effective quality control and for regional trade of agricultural inputs and products, which become increasingly important as climatic conditions change.
- e. Concerning the water sector, access to drinking water is an important topic on the political agenda in many countries in Sub-Saharan Africa. Water scarcity hampers socioeconomic development and is of particular importance for the poorest sector of the population. Challenges which are already prevalent will increase with climate change.
- f. Finally, in the human health sector, the effects of climate change will lead to diseases disproportionately affecting the population in Sub-Saharan Africa. At the same time, extreme weather events can also adversely affect the ability of institutions and organizations of the health system to maintain their services (for example, due to flooding). To effectively protect human health and contribute to the Sustainable Development Goals in times of climate change, the health sector needs to adapt its services, products, systems and processes. Quality infrastructure provides the services required

for systematic quality management to effectively and efficiently implement these adaptations.

Moreover, in terms of the four country studies selected, the study presented here draws the following conclusions:

- i. In Kenya, climate change adaptation is considered a priority on the political agenda. The country thus appears to be a relevant and suitable cooperation partner for designing and implementing projects related to quality infrastructure for responding to climate change. The agricultural sector seems to be especially relevant for such projects.
- ii. In Ethiopia, opportunities for collaboration on quality in the context of climate change stand out in the agricultural and water sectors. The respective ministries have recently launched strategies for climate-resilient development in response to the high exposure to climate change-related risks in the sectors.
- iii. In Uganda, the forecasted impacts of climate change are being taken very seriously. An institutional framework has been built and relevant policies and strategies are in place. By creating awareness about the relevance of quality infrastructure and fostering cooperation between the Climate Change Department (which acts as a coordinating body), the respective ministries and the organizations of the quality infrastructure, an entry point can be created for supporting the development of the quality infrastructure services needed in relevant sectors.
- iv. Finally, Benin puts a clear focus on the agricultural sector in its overall socioeconomic development strategy and climate change policy. For this reason, collaboration for strengthening quality infrastructure services should support sustainable agriculture and economic growth and be in line with the country's climate change targets.

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Abbreviations

4E	Energy Efficient End-use Equipment, International Energy Agency
AC/DC	Alternating Current/Direct Current
ABeNOR	Agency for Standardization and Quality Management of Benin – Agence béninoise de normalisation et de gestion de la qualité
ABMCQ	Metrology and Quality Control Agency of Benin – Agence béninoise de la métrologie et de contrôle de la qualité
AF	Adaptation Fund
AFIMETS	Intra-Africa Metrology System
AFRAC	African Accreditation Cooperation
AFIMETS	Intra-Africa Metrology System
AMCOMET	African Ministerial Conference on Meteorology
ANM	National Agency for Standardization, Metrology and Quality Control – Agence Nationale de Normalisation, de Métrologie et du Contrôle Qualité
ANSI	American National Standards Institute
AREI	Africa Renewable Energy Initiative
ARSO	African Organization for Standardization
ASCP	American Society for Clinical Pathology
BIPM	International Bureau of Weights and Measures
BMBF	Federal Ministry of Education and Research – Bundesministerium für Bildung und Forschung
BMUB	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety – Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit
BMZ	German Ministry for Economic Cooperation and Development – Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung
BOC	Board of Certification
CEN	European Committee for Standardization – Comité Européen de Normalisation
CFC	Chlorofluorocarbon
CIF	Climate Investment Fund
DAkks	German Accreditation Institute – Deutsche Akkreditierungsstelle
DTU	Technical University of Denmark
DWD	German Meteorological Service – Deutscher Wetter Dienst
EAC	East African Community
EASC	East African Standards Committee
EC	European Commission
ECAE	Ethiopian Conformity Assessment Enterprise
EMLA	Ethiopian Medical Laboratory Association
ENAO	Ethiopian National Accreditation Office
ESA	Ethiopian Standards Agency
EUEI PDF	European Union Energy Initiative Partnership Dialogue Facility
FAO	Food and Agriculture Organization
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIZ	German Society for International Cooperation – Gesellschaft für Internationale Zusammenarbeit
GLP	Good Laboratory Practice
HCFC	Hydrochlorofluorocarbons

HFC	Hydrofluorocarbons
HCWH	Health Care without Harm
IAF	International Accreditation Forum
ICRAF	World Agroforestry Centre
IEC	International Electro-Technical Commission
IFAD	International Fund for Agricultural Development
IKI	International Climate Initiative
ILAC	International Laboratory Accreditation Cooperation
INDC	Intended National Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
ISO	International Organization for Standardization
ISTA	International Seed Testing Association
JMP	Joint Monitoring Programme
KfW	Kreditanstalt für Wiederaufbau
KEBS	Kenya Bureau of Standards
KENAS	Kenya Accreditation Service
LIHI	Low Impact Hydropower Institute
NAMAs	Nationally Appropriate Mitigation Actions
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
NMIE	National Metrology Institute of Ethiopia
NOMCI	Network of Official Medicines Control Laboratories
OECD	Organisation for Economic Cooperation and Development
OIML	International Organization of Legal Metrology
OMCL	Official Medicines Control Laboratories
PMPA	Pharmaceutical Manufacturing Plan for Africa
PPCR	Pilot Program for Climate Resilience
PTB	National Metrology Institute of Germany – Physikalisch-Technische Bundesanstalt
PV	Photovoltaics
SADCMET	Southern African Development Community Cooperation in Measurement Traceability
SANAS	South African National Accreditation System
SDG	Sustainable Development Goals
SPS	Strengthening Pharmaceutical Systems
SREP	Scaling Up Renewable Energy in Low Income Countries Program
SSA	Sub-Saharan Africa
TDR	Special Programme for Research and Training in Tropical Diseases
TÜV	Association for Technical Inspection – Technischer Überwachungsverein
U4E	UN Environment – Global Environment Facility/United for Efficiency
UEMOA	Union économique et monétaire ouest-africaine
UNBS	Uganda National Bureau of Standards
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children’s Emergency Fund
UNIDO	United Nations Industrial Development Organization
UNMA	Uganda National Meteorology Authority
USP	US Pharmacopeial Convention
WFP	World Food Programme
WHO	World Health Organization
WMO	World Meteorological Organization

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